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EDITED BY

[G. CA]REY FOSTER. F.R.S.

AND

[PHIL]IP MAGNUS. B.Sc. B.A

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THE

LAWS OF HEALTH

BY

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THE LONDON SCIENCE CLASS-BOOKS

EDITED BY

PROF. G. C. FOSTER, F.R.S. AND SIR P. MAGNUS, B.Sc. B.A.

THE LAWS OF HEALTH

CONTENTS.

CHAPTER I.

PERSONAL HYGIENE.

CHAPTER II.

AIR.

CHAPTER III.

VENTILATION.

CHAPTER IV.

FOODS.

CHAPTER V.

FOODS (continued).

CHAPTER VI.

WATER SUPPLY.

CHAPTER VII.

REMOVAL OF REFUSE MATTERS.—TOWNS.

CHAPTER VIII.

REMOVAL OF REFUSE MATTERS (continued).—HOUSES.

CHAPTER IX.

COMMUNICABLE DISEASES.

CHAPTER X.

SMALL-POX AND VACCINATION.

THE

LAWS OF HEALTH.

CHAPTER I.

PERSONAL HYGIENE.

§ 1. **Health and Disease.**—HEALTH consists in the proper performance of their duties or functions by all the parts or organs of the body, these organs themselves being perfectly constructed: that is to say, it consists in the normal performance of their functions by normal organs; or we may say, that in a healthy state there is absence of disease or of any marked tendency to disease. It follows from this, that in order to preserve health we must endeavour to prevent disease, and to do this we must study the causes of disease. This study we call the Science of Hygiene.

The causes of disease are *internal* and *external*, —the internal being those which arise within us, as heredity, and the external those which come from outside of us, as the influences of the weather.

The causes of disease are also known as *predisposing* and *determining*. The predisposing causes are those which render us liable to diseases; the deter-

mining causes are those which actually bring about the disease. Thus, if a big man stands up to be shot at in a duel, he is more likely to be hit, other things being equal, than a small one; and so his size is a predisposing cause in favour of his being killed. If he is killed, it is the bullet which is the determining cause. So, too, with hereditary tendencies. For instance, if a man is consumptive, his children are said to be predisposed to consumption; and the fact that the father is consumptive is a predisposing cause, if any of his children become so also.

The most important predisposing causes of disease will be described in the next few pages.

§ 2. **Constitution.**—This is the resultant of all the physiological actions of the system, such as the power of digestion and of circulation, the capacity of the lungs, the muscular strength, and many others. It is said to be strong when all these actions are well performed, and weak when one or more of them is defective. A strong constitution may be converted into a weak one by bad habits, and conversely a weak one may often be much strengthened by careful attention to the laws of health. The most remarkable example of this on record is perhaps the case of Luigi Cornaro, a Venetian nobleman, who—although originally, as he tells us, of a weak constitution, which he still further damaged by indulging in various kinds of excesses until he was nearly forty years of age,—by persisting in the observance of a temperate course of living, not only recovered a perfect state of health, but wrote a treatise entitled 'Sure and certain Methods of obtaining a Long and Healthful Life,' when he was eighty-

six years old, and, 'after passing his 100th year, died without pain or agony, and like one who falls asleep.'[1]

§ 3. **Temperament.**— Galen, perhaps the most celebrated of the ancient physicians after Hippocrates, pointed out that there are, as it were, different kinds of healthy people, and he described the characteristics of various groups or classes of individuals to which he gave the name of 'temperaments.' Of these, the most important, and the only ones that are still recognised, are the nervous, the sanguine, and the lymphatic temperaments. Temperament may be defined as a marked predominance of one of the three general systems of the economy. Persons of a *sanguine* temperament are robust, with strong circulations and respirations and great animal spirits—typically healthy persons who rarely become diseased, and when they do so, soon get well. In the *nervous* temperament, the nervous system has too marked a predominance over the other systems of the economy. The importance of this consists in the fact that with a pronounced nervous temperament, there is a predisposition to nervous diseases; and, indeed, this condition ought to be looked upon rather as one of a marked tendency to disease, than as a healthy state. The *lymphatic* or *phlegmatic* temperament, as it is called, is accompanied by an undue predominance of the lymphatic or absorbent system, and is characterised by a listlessness and inactivity which form a strong contrast to the unceasing rest-

[1] *Spectator*, vol. iii. No. 195.

lessness so typical of the nervous temperament; but like the latter, when well marked, the so-called lymphatic temperament is nothing more than a condition of strong predisposition to disease, viz. to scrofula. The tendency to nervous diseases shown in well-marked nervous temperaments, requires to be combated in children by judicious restraint, and especially by frequent change of occupation. Children of a lymphatic temperament require to be encouraged and even stimulated to work, and sometimes even to play, and it is especially important that they should be placed in the best possible conditions as regards food, good air, clothing, &c., and should not live in damp, unwholesome houses, as those are the conditions that especially favour the development of scrofula and consumption.

§ 4. **Idiosyncrasies.**—Celsus, another celebrated ancient physician, said that each person has a weak point in his constitution to which he should specially attend, in order that he may be able to ward off the diseases which are most likely to attack him. Such individual peculiarities we call 'idiosyncrasies,' and some of them are of great importance. Some persons are liable to disorders of the digestive apparatus, and have to take great care what they eat. Others take cold easily, and have to beware of exposing themselves to inclement weather, and so on. Again, the same cause will produce different diseases in different persons, according to their idiosyncrasies. Thus, if a regiment of men encamp on marshy ground, one man may get a sore throat, another a cold in the head, another bronchitis, another rheumatic fever, another

rheumatism, another intermittent fever or ague, and another—nothing at all; the reason of all this being that each man was attacked in his weakest point. There are certain diseases, as small-pox, scarlet fever, enteric (typhoid) fever, and other communicable diseases, one attack of which confers, as a rule, immunity from the same disease for the rest of life; but there are occasionally persons who are attacked by one of these diseases twice, three times, and even oftener. These persons afford a remarkable instance of an idiosyncrasy, and one that cannot be accounted for in any way—one, too, that it is of the greatest importance to notice, as we shall see in the chapter on small-pox.

§ 5. **Heredity.**—Just as external resemblances and even sometimes accidental malformations descend in families, so do resemblances in the construction and working of the internal organs, and thus it happens that tendencies towards certain kinds of disease are frequently hereditary. This is most marked, perhaps, in the case of nervous diseases—such as epilepsy, St. Vitus's dance, and the various forms of madness—not that any one nervous disease is necessarily hereditary, but the general tendency to such diseases. So too, consumption, the great plague of temperate climates, is undoubtedly hereditary, although it does not follow that a person belongs to a consumptive family because he is attacked with this disease. Many fall victims to it from being placed in conditions suitable to its development, and especially from living in bad air or in damp houses. Gout is another good example of a hereditary disease. It may be acquired

by over-indulgence in rich food and strong wines, and the tendency to it is implanted in succeeding generations. Scrofula, cancer, and many other diseases are more or less frequently hereditary. In order to combat this hereditary tendency to diseases, certain precautions should be adopted. In the first place, it is necessary that persons who have a hereditary tendency to a disease should be placed in conditions unfavourable for the development of that disease. Thus, persons belonging to consumptive or scrofulous families should carefully avoid living in a close atmosphere or in damp houses; persons with a tendency to gout should be very moderate in eating and drinking; and so on. It must also be remembered that the tendency to a hereditary disease is enormously increased if this disease is common to both sides of the family (both father's and mother's); and so a person belonging to a family in which nervous diseases are prevalent should not marry into a nervous family, lest the descendants suffer from severe nervous diseases, and even from insanity. So, too, a person belonging to a consumptive family ought not to marry one who has a like tendency, lest consumption in its worst forms afflict the children. And just as defects in the various parts of the body are liable to be transmitted from generation to generation, so is perfection in the construction and working of these parts, and thus a tendency to long life is hereditary.

§ 6. **Age.**—We are subject to different diseases at various periods of life, and so age is an important predisposing cause of diseases. Shakespeare, in his play of 'As You Like It,' divides the life of man into

seven ages, and this is generally accepted as the most natural division that has been proposed; but for our purpose, that given by Hallé, into five periods, is quite sufficient. These are (1) infancy; (2) childhood; (3) youth; (4) manhood; (5) old age.

(1) **Infancy.**—The first great danger to life is from the external cold. Although the circulation and respiration of infants are so quick, and the amount of oxidation going on in their blood so great that they produce a very large amount of animal heat, yet they run a much greater risk of being chilled than adults do, and the reason is that they are small, and that small bodies have large surfaces. The smaller a body is, the larger is its surface in proportion to its contents. Now, we lose heat very largely from the surface of the skin, and a child's external surface being so much larger than an adult's in proportion to his size, he loses heat a great deal faster, and so gets chilled more easily. The normal temperature of the blood is about 100° Fahrenheit. If it is chilled more than a very few degrees death ensues, as happens when infants are wilfully exposed to the cold, and are said to be frozen to death. But what happens much more frequently is that they catch cold, and in some internal organ, generally the lungs,—bronchitis, or inflammation of the lining membrane of the air-passages, being their most common complaint, and one from which great numbers of infants die. It is very important, then, that infants and young children should not be exposed to cold. Every part of their bodies except the head should be covered warmly in winter,

lightly in summer, but still covered, and they should not be allowed to go about with bare legs and arms and low-necked frocks, as is too commonly the case. The other great danger to infants arises from insufficient or improper food. Milk contains all that is necessary for their sustenance. It is their natural food, and the only one that they are able to digest. It is only after some teeth have appeared at the age of seven or eight months that the increased activity of the salivary glands enables them to digest starchy foods. From improper feeding children get disorders of the digestive apparatus, vomiting, diarrhœa, &c., frequently accompanied by convulsions. They may also suffer from rickets—a terrible disease, in which the bones are too soft, and so readily become bent out of position—various malformations resulting which remain throughout life, and one of the worst of which is an alteration in the shape of the chest, resulting in an impeded respiration. The communicable fevers—small-pox, measles, scarlet fever (or scarlatina, which is the same thing), whooping cough, diphtheria, and chicken-pox, are especially diseases of infancy and childhood, and it is extremely important that infants and young children generally should be kept out of the way of these complaints. The most terrible of them is small-pox, the mortality from which, as will be shown in a succeeding chapter, may be almost entirely prevented by vaccination; and it is consequently required by law that every infant should be vaccinated within three months after its birth, unless the medical attendant certifies that there is some special reason to the contrary. The disturbance caused by vaccina-

tion is so slight, that parents, especially in the presence of an epidemic of small-pox, do well to have their children vaccinated at a month or six weeks old. (See Chapter X.)

(2) **Childhood.**—The diseases mentioned last under 'Infancy' are the most characteristic diseases of childhood, but it must be remembered that no child need have any of them, and that the tendency to take them decreases with age. Sometimes, when what is called a mild epidemic of measles or whooping cough prevails, healthy children are actually taken by their parents to houses in which the disease has broken out, in order that they may take it and have done with it, in the hope that they may take a mild form of it, and so perhaps escape taking it severely at a future time. This is a most pernicious practice. A large number of children die from measles or whooping cough, or rather from the colds they take while recovering from those diseases, and a still larger number have their lungs damaged for life, especially after whooping cough; and so parents, by exposing their children to the danger of taking these diseases, make them take a disease which they might never have had, which may kill or maim them for life, and which, at any rate, no one can say is likely to do them any good. At about five years of age, what is called 'the second dentition crisis' begins. At this time a child has all its first set of teeth, twenty in number, and all its second set of teeth except the four wisdom teeth, twenty-eight in number, or forty-eight altogether, in its jaws at once. The second set, or permanent teeth, growing below, and displacing the first set or tem-

porary teeth, render children at this age irritable and fractious, and cause them sometimes to suffer from convulsions. Children require not merely to replace the losses that take place from their bodies, but, as they are growing fast, they require to add new material. They therefore must be fed often; for, as Hippocrates truly said, 'Children do not well support a fast.' They also require plenty of sleep, and their exercises, whether mental or bodily, ought not to be too prolonged, and should be varied as much as possible. Bad air is especially fatal to children, and a high children's death-rate is a sure sign of general insanitary conditions, especially as regards the want of removal of refuse matters.

(3) **Youth.**—This is the period of life at which consumption is most prevalent and most fatal, its determining causes being especially *overcrowding*, which results in the same air being breathed over and over again, living on a *damp soil*, and working in places where there is much *dust* in the air. Anæmia, or bloodlessness, characterised by paleness of the skin, palpitation of the heart and hurried respiration, is also very common among young people who work for hours in overcrowded, badly-lighted rooms. While most of the communicable fevers are diseases of childhood, enteric or typhoid fever is especially a disease of youth. This may be due partly to the fact that infants and young children, being fed largely upon milk, do not run so great a chance of drinking the poison as persons who drink water; for children, and even infants, suffer equally from typhoid fever when milk diluted with water containing the

poison of this disease is given them to drink. Small-pox is prevalent at this time of life among those who have not been revaccinated before they are fifteen (or before twelve in the presence of an epidemic of small-pox), as will be further explained in the last chapter. Rheumatic fever, a disease often produced by sitting for hours in wet clothes, or by some similar imprudence, although common in childhood, is still more prevalent in youth, and is frequently followed by heart disease, which lasts for the rest of life.

(4) **Manhood.**—Now growth is completed, the individual has run the gauntlet of the communicable diseases, of consumption, and of all the various other risks to life that attend childhood and youth. His habits have been formed, and influence largely the diseases to which he is liable during the remainder of his life. These diseases are for the most part chronic diseases: that is to say, they are diseases of which he does not get cured. He may get better for a time, but he does not get well. The disease is, as it were, part and parcel of him. Chronic bronchitis, arising from neglected colds, is the most common and the most fatal disease in this and the later periods of life; next come heart diseases, which are generally the result of rheumatic fever contracted during youth. Diseases of the liver and kidneys—very largely brought about by intemperance; chronic indigestion, resulting in the want of absorption of nutriment and a degeneration of the various tissues of the body, due in most cases to the same cause; with gout and cancer, especially towards the latter part of this period, are the

next most important diseases of manhood. Although nervous diseases are common throughout life, paralyses of various kinds now become an important agent in producing death, and apoplexy is only a little less fatal.

(5) **Old Age.**—Bronchitis, paralysis, and apoplexy are the great agents of death in old age, and in the order in which they are mentioned. Old people are extremely susceptible to cold. Their circulations and respirations are slow; the elasticity of the air-cells of the lungs is impaired; the aërating surface of the lungs is less, owing to the permanent enlargement of some of the air-cells at the expense of the rest, so that the oxygenation of the blood is less perfect, and less animal heat is produced. They are therefore less able to resist cold, and so in severe winters large numbers of them die from bronchitis. The action of the skin as an excretory organ becomes more and more languid as age advances, and its work being thrown upon the other excretory organs, the lungs and kidneys, the tendency of these to become diseased is increased. It is therefore necessary, especially during the latter part of manhood and during old age, that the action of the skin should be stimulated by baths, by rubbing, and by exercise. Paralysis has been mentioned, but apart from this the signs of impaired nervous action are very characteristic of old age. The senses gradually become blunted, as is most obvious in the cases of sight and hearing: and in extreme old age, known as decrepitude, the memory is lost, and the stage so graphically described by Shakespeare is arrived at:—

'Last scene of all
That ends this strange eventful history,
Is second childishness and mere oblivion;
Sans teeth, sans eyes, sans taste, sans everything.'

§ 7. **Sex.**—Males die at a greater rate than females at every period of life. Thus, in England, during the ten years from 1871 to 1880 inclusive, twenty-three males out of every thousand males died annually, while only twenty females died out of each thousand. Of children under five years of age, sixty-eight boys and fifty-eight girls out of each thousand died annually, and of persons from twenty to forty-five years of age thirty-two men and twenty-seven women. So that whether we consider young children or grown-up people, it is true that in each case more males died than females. This has been sometimes attributed to the fact that men are more careless than women as regards eating and drinking, exposure to the weather and dangers of various kinds; but when we find that among infants and young children the same law holds good, it is clear that there is some predisposing cause at work which determines the greater mortality among males. Most diseases kill more males than females. This is especially noticeable in kidney diseases (very largely the result of over-eating and of spirit drinking), lung diseases—the result of exposure, brain diseases—often brought on by over-anxiety, whilst accidental deaths and suicides are also far more common among males than females. Females, on the other hand, are more subject to cancer than males are. They are also more subject at all ages to diphtheria, whooping-cough, and the continued fevers (typhus, enteric, and

simple continued), although they are less subject to the other important diseases of the same class, as small-pox, measles, and scarlet fever. Consumption kills almost exactly as large a proportion of females as of males, if we take all ages together; but while from ten to twenty years of age it kills far more young women than young men, after forty-five years of age it kills more men than women.

§ 8. **Habits.**—We take notice of a new sensation the first time that we experience it. When we taste an article of food for the first time, when we hear a sound to which we have not been accustomed, or see a strange object, it attracts our attention; the second time we notice it less, and if the sensation is repeated we become gradually accustomed to it. It is thus that habits are formed; and when a habit is formed, it becomes, as it were, part of ourselves, a sort of artificial necessity, and it is difficult, the more so the longer the habit has been practised, to break ourselves of it even if we try to do so.

> 'How use doth breed a habit in a man!'
> *Two Gentlemen of Verona*, Act i. Scene 2.

Thus it is of the greatest importance to our well-being that we should form habits that are beneficial, and not such as are hurtful, to us.

Habits may be either important aids to the preservation of health and the prolongation of life, or on the other hand they may be important predisposing causes of disease. Food will be considered in a separate chapter, but it is necessary to observe here that it is of the greatest importance for young people

to be taught to masticate their food carefully, and to eat slowly, as quick eaters generally suffer from indigestion later in life. The habit of eating pungent condiments, as cayenne pepper, &c., should be discouraged, as these substances produce an unnecessary irritation of the mucous membrane of the stomach. Persons who live to a great age, as a rule, do not touch even mustard and common pepper. Growing people require more food than adults, as they have not merely to replace the losses continually occurring, but to increase in weight as well. As Dr. Parkes says :—'In youth most harm is done by taking too little food, and after fifty years of age most harm is done by taking too much.' Very old people are always spare eaters. Thus Luigi Cornaro, the centenarian already referred to, tells us that his diet consisted of twelve ounces of food a day, and fourteen ounces of wine, and that he made himself seriously ill by increasing it for a short time, at the recommendation of his friends, to fourteen ounces of food and sixteen of wine. The evils of intemperate habits as regards drinking will be referred to in a future chapter. It is sufficient to say here that alcoholic stimulants of all kinds are at least perfectly unnecessary for young people. Smoking, on the other hand, is certainly pernicious, even in what is called 'moderation,' to young and growing persons. To quote Dr. Parkes again :—'Boys who smoke much are less disposed to bodily exertion. Smoking interferes with appetite, impairs bodily activity, and in some way must damage the circulation or the composition of the blood. Add to *this that* a young man without the least good to

himself is forming a habit which may become very burdensome to him, and that if he is a poor man he is spending money for which there are fifty better and more pressing applications.' The regular removal of waste substances from the body is most necessary for the preservation of health. If they are not removed, they are partly re-absorbed into the blood, the quality of which is thus deteriorated, and so the nourishment of the tissues is seriously impaired. It is certain that many of the diseases of middle age are either actually caused, or at any rate aggravated, by the want of proper attention to this matter. The organs by which these substances are removed are the skin, the lungs, the kidneys, and the intestines. The most important agents in regulating the action of the first three are cleanliness and exercise. With regard to the last, the formation of a regular habit early in life is essential, and bodily exercise also stimulates the action of the intestinal canal. If the skin is not kept thoroughly clean, the dead scales of the epidermis, or scarf skin, which ought to be removed, accumulate upon the surface, and impede the proper action of the glands of the skin. Now, this action naturally becomes weaker during the later periods of life, and it is only by practising habits of cleanliness throughout life that we can preserve the action of the skin as long as possible. If the skin does not do its work properly, more has to be done by the lungs and kidneys, and these, having too much to do, are more likely to become diseased. The cold sponge-bath taken in the morning is not only cleanly, but is a valuable tonic to the system generally, and should be taken regularly

daily throughout the year by all who experience a feeling of warmth—the 'reaction' as it is called—after it. On the other hand, it is mischievous to those who, by reason of a weak circulation or of advancing age, are chilled by it. These should take a bath in the morning at a temperature only a little below that of the surface of the body. A warm bath when used for cleansing purposes should be taken the last thing at night, as it renders the skin more sensitive to changes of temperature, and if taken earlier in the day makes persons liable to catch cold.

Attention to the teeth is also a most important matter. All people who live to a great age have good teeth. Cornaro tells us that at eighty-six years of age his teeth were 'in as good a condition as ever they were in the briskest days of my youth;' and although we may allow a little for the old man's imagination, we may gather that he had a good set of teeth and took care of them. The teeth should be brushed well all over at least twice a day, and those that show any signs of decay should be at once attended to. Every tooth prevented from decaying gives an additional prospect of a long life. It is important, too, to keep the hair well brushed and cleansed; but as this is a matter more generally recognised, it need not be further mentioned. It is a mistake to suppose that it is not necessary to use oil or pomade of some kind for the hair. In the majority of individuals the sebaceous glands do not secrete sufficient of the oily substance to keep the hair moist, and so it becomes too dry, and is much more liable to fall off.

§ 9. **Exercise.**—A certain amount of exercise is absolutely necessary for health. It not only promotes the action of all the excretory organs, and especially of the lungs, but it is necessary for the maintenance in a proper condition of all the tissues of the body. Parts grow when they are properly exercised, and waste away when they are either not sufficiently worked or over-worked. Rest is as essential as exercise, for while during exercise the tissues that are used waste, it is during rest that they are repaired. Growing children and young people are not capable of as great or long-continued exercise, either mental or bodily, as grown-up people, and it is more necessary that their time should be subdivided, and that they should not be kept too long at any one kind of work. The best form of bodily exercise, especially for those who have a limited amount of time at their command, is no doubt a complete system of gymnastics, by means of which all the muscles are brought into play in turn. Nearly as good, but not always so easily attainable, is swimming, an art which should be learnt by everybody. While fully grown persons are able to do more work of all kinds than young people, they require less sleep. For children nine hours' sleep out of the twenty-four is none too much. It is a great advantage to health to go early to bed and to rise early in the morning. Most very old people have been early risers. The late eminent judge, Lord Mansfield, made a practice of enquiring of aged witnesses to what they attributed their long life, and he almost invariably found that, however much they differed in other matters, they had all been early risers.

§ 10. **Clothing.**—As has been already mentioned, it is especially essential that infants, young children, and aged persons should be warmly clothed, because they cannot stand the cold. During youth and middle age this is a matter of less importance, only it should always be remembered that warmer clothing should be put on after exercise. In cold weather, at any rate, the chest should be very well covered, the practice of wearing open-fronted waistcoats without any additional protection to the chest being a very dangerous one. On the other hand, it is not a good plan to wear a comforter round the neck, as it makes the skin of that part very sensitive to cold, and sore throats are the result. The neck should either be covered always or not at all. The practice of tight-lacing is very pernicious, especially to young people. It displaces the liver and othér internal organs, prevents the proper development of the chest, impedes respiration, and therefore interferes with the oxygenation of the blood and the nourishment of the body generally. Boots that fit the feet and are neither too loose nor too tight should be worn. They should have broad soles and be wide and not pointed at the toes, or the feet will become deformed and corns be produced. This is an exceedingly important matter, and the want of attention to it causes great discomfort later on in life. High heels should never be worn : they throw the body forward and necessitate an awkward gait.

An upright position, whether in sitting or walking, is very advantageous for the due expansion of the chest.

CHAPTER II.

AIR.

§ 11. **Composition of Air.**—The air, in which we move and which we breathe, is a material substance. We feel it when the wind blows in our faces, and we can, by means of a suitable apparatus, weigh it. On account of its weight it exercises a pressure on things at the surface of the earth equal to about fifteen pounds on every square inch. It consists of a mixture of gases called oxygen, nitrogen (with argon), and carbonic acid. In 10,000 parts of air, it is found that there are on an average 2,096 parts of oxygen, 7,900 of nitrogen, and only *four* of carbonic acid. These numbers vary very slightly in the air out-of-doors, but may vary much more in foul air in confined places. That is one of the reasons why we know that the air is a mixture, and that the gases in it are not chemically combined. One of the properties of all gases is that they spread equally throughout the place in which they are, and so we find that the composition of pure air which is a mixture of gases, varies very little in different places and at different heights above the level of the sea, so that the carbonic acid, which is much heavier than either of the other gases, does not collect upon the surface of the earth, but is spread through the whole atmosphere. The air is also capable not only of holding moisture in suspension in the form of mist or fog, but also of holding it in the condition of vapour so *that it cannot be seen*; in fact it dissolves it, just as

water dissolves sugar, and the warmer the air is, the more moisture is it capable of dissolving.

§ 12. **Action of Respiration.**—The respiratory apparatus consists of the walls of the chest enclosing the chest cavity, the lungs which are contained in that cavity, and the air-passages connected with the lungs. The chest cavity itself is a closed cavity not in communication with the external air, but it is capable of being enlarged by means of its movable walls. The interior of the lungs, on the other hand, is directly connected with the external air by means of the windpipe which opens out into the pharynx (the cavity at the back part of the mouth); for the wind-pipe divides into two branches called bronchi, which go one to each lung, and there subdivide into numerous smaller branches, upon the ends of which are placed the little elastic air-sacs of the lungs, around and between which the capillary blood-vessels ramify. The cavity of the pharynx communicates with the external air both by the mouth and by the passages of the nose, but the latter are, properly speaking, the respiratory passages. The wind-pipe and air-tubes of the lungs are kept always wide open by rings or patches of cartilage contained in their walls, and so these air-tubes and the little air-sacs are always full of air. The blood in the capillary vessels which ramify on the walls of these air-sacs is venous blood brought by the pulmonary artery to the lungs. It is blood, therefore, which contains too much carbonic acid gas and too little oxygen gas, and it is separated from the air inside the air-sacs only by the walls of the capillary *blood-vessels* and the fine membrane of which the air-

sacs are made, that is to say by a moist, fine membranous structure. The result is that some of the carbonic acid gas passes through this moist membrane into the air in the air-sacs, and some of the oxygen gas passes from the air in the air-sacs, through the same membrane into the blood in the capillary blood-vessels. In order that this process may continue, the air in the air-sacs must be frequently renewed, and this is done in the following way :—The external layer of muscles between the ribs contract, and by so doing raise the ribs and breast-bone and thus make the chest wider from side to side and from front to back; at the same time the diaphragm—the muscular partition at the base of the chest, which separates that cavity from the abdomen—contracts and becomes flatter, thus increasing the depth of the chest from the neck downwards. Thus the chest cavity is made larger in all directions by the contraction of these muscles. Since then the external air cannot get directly into the chest cavity itself, it presses through the air-passages of the lungs and distends the little elastic air-sacs so that the lungs are made large enough to fill the enlarged cavity of the chest. Thus a certain amount of fresh air is added to the air already contained in the lungs, and this action is called 'inspiration.' As soon as this has happened the muscles in question cease to contract. The ribs are no longer held up, and so the pressure of the external air forces the chest walls back into their original position and reduces the cavity of the chest to its original dimensions. At the same time the little elastic air-sacs partially collapse upon the air contained in them and force a portion of it out through

the air-passages into the external air. This is called 'expiration.' Now it is found that the air that is breathed out, instead of containing only *four* parts of carbonic acid in 10,000, contains about 470 parts of this gas in 10,000, and that while the carbonic acid in it has been thus increased, the oxygen it contains has been diminished to a somewhat greater extent—the amount of nitrogen remaining practically the same. It is found also that whether the air which is breathed in be warm or cold, dry or moist, the air which is breathed out is always nearly as warm as the blood, and always contains as much aqueous vapour as it is capable of holding. So we see that in the lungs water, as well as carbonic acid, is got rid of from the blood, while at the same time heat is lost. The oxygen which passes into the blood from the air in the lungs combines with waste matters in the blood, and with some of the substances derived from the foods, and the result is the production of water, carbonic acid, and the substance (containing nitrogen) called 'urea'—bodies which are capable of being separated from the blood by the various excretory organs. The blood is thus rendered fit to nourish the tissues of the body. If the necessary oxygen cannot be obtained, or is obtained in too small a quantity, waste substances accumulate in the blood, which is consequently rendered unfit to nourish the tissues of the body; and when oxygen is altogether withheld suffocation is the result. Since animals are continually taking oxygen out of the air it must be replaced, and this is done by plants, which absorb carbonic acid from the air and decompose it, *retaining* the carbon to assist in the formation of their

tissues and setting the oxygen free into the air. It is the green parts of the plants that do this, and only in the daytime. The flowers of plants and ripening fruits, on the contrary, absorb oxygen and give out carbonic acid. It is, therefore, not advisable to keep plants, and especially flowering plants, in sleeping rooms. Air which has been once breathed is not fit to breathe again. It contains too much carbonic acid, far too little oxygen, is too moist and also contains a small quantity of foul organic matter. But carbonic acid gas, although a poisonous gas in itself, is not present in the air that is breathed out in sufficient quantity to produce any marked effect. It is the diminution of oxygen and the presence of foul matter in the air which has been breathed which makes it unfit to breathe again. In fact the amount of carbonic acid is taken as the measure of the impurity of air that has been breathed because the other defects are proportional to it. Now expired air contains nearly 120 times as much carbonic acid as inspired air. On the average a man inspires and expires between sixteen and seventeen cubic feet of air in an hour. Since then the air he expires contains about 120 times too much carbonic acid it will require about 120 times its volume of air to dilute it so that it shall be fit to breathe again—that is to say about 2,000 cubic feet: so that each person requires as much as 2,000 cubic feet of fresh air every hour. It is, however, found practically that this amount is not sufficient to prevent the air of a room in which persons are breathing from becoming stuffy—the stuffiness being caused by the presence of the foul organic

matters just mentioned, and that 3,000 cubic feet at least are required every hour for each person in order to keep the air fresh. In the air of crowded rooms the proportion of oxygen does not vary much from the normal amount, being seldom lower than 2,070 parts in 10,000 of air, and as low only in very foul atmospheres, so that we must regard the ill effects of breathing such air for a lengthened period, and especially of living in such atmospheres, as chiefly due to the presence of foul matters in it. These effects are, poorness of the blood, exhibited especially in a deficiency in the amount of red corpuscles, producing the condition known as anæmia or bloodlessness, which results in imperfect nutrition of the various tissues of the body, and is accompanied by headache, palpitation of the heart, and hurried breathing. Among persons who live in such atmospheres consumption is also so prevalent that it has been considered by some authors that the breathing of air which has been breathed before is perhaps the most important cause of consumption. It is in such atmospheres (when the overcrowding is carried to excess and the air becomes very foul indeed) that typhus fever finds the conditions under which it spreads.

§ 13. **Ozone.**—Pure air also contains in small quantity a body which is capable of decomposing and rendering harmless foul organic matters with which it comes in contact. This substance is called *ozone* (from the Greek word for smell), because it has a peculiar odour. It is another form of oxygen more condensed and more active in its properties than ordinary *oxygen,* so that it is capable of combining directly

with substances, such as silver and mercury, which oxygen will not oxidise directly, and it is much more effective in decomposing foul organic matters than ordinary oxygen is. This body is contained in the air that blows over the land from the sea, and is also found in the air during thunder-storms and during a fall of snow; and it was shown by Dr. Daubeny, of Oxford, that plants in giving out oxygen give out a small quantity of it in the form of ozone, and that scented flowering plants do this to a remarkable extent, so that the air around flourishing vegetation almost always contains ozone. This body is never found in foul air, and if introduced into it it oxidises the foul matters at once and renders them harmless. Its presence or absence in the air has been by some supposed to be connected with the absence or prevalence of various diseases. The facts, however, are insufficient to warrant any such conclusion, and we can only regard ozone at present as a substance which decomposes foul organic matters and so purifies the atmosphere.

§ 14. **Dust.**—The solid particles suspended in the air as dust consist of mineral substances, as common salt, fine sand, &c.; dead organic matter, as scales of the epidermis (or scarf skin); and living bodies, as the pollen of plants, the spores of fungi, and the germs of the lowest forms of animal and vegetable life. The air in and near large towns also contains finely divided carbon in the form of soot, produced by the incomplete combustion of substances used for warming, especially of coal. In many manufacturing operations dust is produced in the air, consisting sometimes of

mineral matter as in mines, porcelain works, metal-turning, marble-polishing, manure works where bones and mineral phosphates are ground up in mills, and sometimes of organic substances as in the spinning of cotton and wool. The breathing of air containing much dust of any kind in it produces irritation of the respiratory apparatus, and causes coughing; and from the fact that small particles get into the lungs and set up irritation there, lung diseases of various kinds and even consumption are prevalent amongst those who are exposed to such air. It is very important, therefore, that they should breathe through the nose in order that as much as possible of the fine dust in the air may be arrested, and so not get into the lungs; and there can be no doubt that by the use of a very simple form of respirator containing a little cotton wool through which the air inspired might be filtered and the dust prevented from getting into the lungs, the death-rate from consumption among those who work in such atmospheres would be very much reduced.

§ 15. **Lighting and Warming.**—The substances used for lighting and warming rooms contain carbon and hydrogen as their chief constituents. When they are burned, therefore, carbonic acid and water are produced in the air, and so the use of these substances causes an increase in the amount of carbonic acid in the air, whenever the products of combustion are allowed to escape into the room, as those from lights almost always are. When the combustion is not perfect, particles of carbon escape unburnt into the air as soot, and under some circumstances partially burnt fats of an acrid and

irritating nature, and also a very poisonous compound of carbon and oxygen called carbonic oxide gas, escape into the air, so that when the combustion of these substances is imperfect the air is rendered much more impure than when they are completely burnt with the production of carbonic acid and water. Of candles the best for health are the harder kinds, made of stearine, wax, paraffin, spermaceti, &c., because these substances do not melt so quickly as tallow, which rises up the wick faster than it can be completely burnt. The best lamps for burning oils in are those with a circular wick or with two flat wicks parallel to one another. The combustion is more perfect as air is directed into the interior of the flame. Mineral oils are dangerous to use unless rectified, as the crude oils contain volatile compounds of carbon and hydrogen which are given off as vapour when the lamp becomes warm and which form an explosive mixture with the air. Gas is produced by distilling coal in large iron retorts. Coke is the residue, and the substances that are distilled over consist of tar, which is separated in a special receiver and is the material from which carbolic acid and the aniline dyes (mauve, magenta, &c.) are prepared; ammonia, which is separated by washing the gaseous products of the distillation with water, in which the ammonia dissolves, forming the ammoniacal liquor of the gas-works, from which the salts of ammonia used as manures are prepared; sulphuretted hydrogen and other compounds containing sulphur, which are partly separated by the passage of the gas over lime or over oxide of iron; and finally the coal gas, which is col-

lected in gasometers, and consists of a mixture of light and heavy carburetted hydrogen with free hydrogen, carbonic oxide, and smaller quantities of other substances, as compounds containing sulphur. The result of the perfect combustion of coal gas is carbonic acid and water with small quantities of other substances, as of sulphurous and sulphuric acids; and it is worth noting that there is always sulphuric acid to be found in the air of large towns, which has been derived from the sulphur contained in the coal burned. When gas is imperfectly burnt the same results occur as with the substances mentioned before, and the greatest danger from the use of gas occurs from the possibility of its escape, either through leaky fittings, or on account of carelessness. In the first place it forms an explosive mixture with air, and in the second place (and this is still more important) it is highly poisonous, and even a very slight escape of gas into a house is certain to cause a general state of ill health in the persons living there, and may produce very serious consequences. The poisonous properties of gas are especially due to the carbonic oxide which it contains, and which is an extremely poisonous substance, and has, as Claude Bernard has shown by experiment, a greater affinity for blood than oxygen gas has, so that it will take the place of oxygen in the blood and prevent vital actions from going on. Persons who sit for many hours together in workshops where much light is required and where there are many gas burners, suffer from the effects produced by an insufficient amount of oxygen in the air, and by the presence in it of an excess of carbonic acid, of small

quantities of carbonic oxide, of soot, &c. The effects are much the same as those that have been described as resulting from breathing the air of over-crowded rooms, and there is a high mortality from consumption among these people. It is found that two hard candles, or one good oil lamp, consume as much oxygen and give out as much carbonic acid as one man, so that a man sitting in a room with two candles requires twice as much air as he would were he sitting there without them. One gas burner consumes as much oxygen and gives out as much carbonic acid as four or five men, or even more, according to the light produced, but gas causes a smaller amount of impurity in the air than candles do, in proportion to the light given; as, however, far more gas is commonly burnt than is required for lighting the rooms in which it is used, and as the products of combustion are generally allowed to escape directly into the air, the air is rendered much more deleterious than if candles were used and a much smaller amount of light produced. Electric lighting, which is now becoming very generally adopted, has the great advantage to health that by it the oxygen of the air in the room is not used up, and no deleterious products are formed. In the case of the substances used for heating rooms a means of escape for the products of combustion is now invariably provided by the chimney or flue. Coal is better suited for heating rooms than wood, because it has much greater heating power and causes less dust, and it is better for use than coke because the latter *in burning* produces no smoke, and so the products of *combustion may escape* into the room without any-

one being aware of it. The open fire-place, as commonly used in England, is a very wasteful contrivance inasmuch as 90 per cent. of the heat, or even more, passes up the chimney with the products of combustion. But from a sanitary point of view it is a good one, as by it the air of the room is rapidly changed. Iron stoves of various kinds afford a much more economical method of burning fuel, but they have all the disadvantage of drying the air too much ; and many of them are apt to get over-heated and to cause an unpleasant smell from the charring of organic matter in the air. The most economical are slow-combustion stoves in which coke is burned, being supplied with air from outside the house by a pipe, while the products of combustion are carried away by an iron flue. Although the interior of these stoves is not supposed to communicate with the air of the room, it is found that the air of rooms in which they are used always contains small quantities of carbonic oxide, and so slow-combustion stoves are not, as a general rule, well suited for dwelling-rooms. In the Galton stove and in the Manchester Grate there is an air chamber placed around the flue and communicating on one side with the external air, and on the other with the interior of the room. By this contrivance the air which comes into the room from the outside through this chamber is warmed by contact with the heated flue, and so a much larger percentage of the heat produced by the fuel is utilised, and at the same time fresh air is admitted into the room from outside the house. In the Calorigen stove a tube passes from the outside up through the middle

of the stove and opens out into the room. Slow-combustion stoves, although not advisable in dwelling-rooms, are useful in large buildings where it is required to economise the heat as much as possible, and to this end the external radiating surface is made as large as possible by projecting plates of metal, called gills.

CHAPTER III.

VENTILATION.

§ 16. **Quantity of Air required.**—The results of experiments made by Dr. De Chaumont show that whenever the carbonic acid in the air of inhabited rooms exceeds that in the outer air by 2 parts per 10,000 of air, the air becomes stuffy or close from the amount of foul organic matter and the excess of moisture contained in it, so that 2 parts of carbonic acid per 10,000 of air (or ·2 part per 1,000) above the carbonic acid in the outer air is taken as the index of the limit of respiratory impurity that can with safety be allowed. Now since each individual on an average expires ·6 (or 3 times ·2) of a cubic foot of carbonic acid in an hour, it follows that the air he breathes out must be diluted with 3,000 cubic feet of pure air, so that the carbonic acid in it may be reduced to the above limit of respiratory impurity. The air, then, in dwelling-rooms must be changed; and the question arises as to how often this can be done. It is found *practically that in this* climate the air of a room can-

not be changed more than from three to four times in the hour without causing a draught. If the air is only changed three times per hour, each individual will require to have 1,000 cubic feet of air-space. If it can be changed four times per hour, 750 cubic feet of space for each person will be sufficient to ensure the requisite supply of 3,000 cubic feet per head. The quantities allowed in public lodging-houses, &c., are much smaller than these, but anything below 300 cubic feet per head is usually considered to constitute overcrowding—300 feet for adults per head, with a somewhat smaller allowance for children. Sick persons, especially when congregated together, as in hospitals, require a much larger air-space; and in many instances, as notably in cases of severe operations, and also of infectious diseases, the larger the air-space allowed, and the more complete the change of air, the greater is the percentage of recovery. In such cases temporary wooden or iron hospitals are better than permanent structures. For successful ventilation the air taken must be pure, and must pass continually into the room, sufficient provision being made for the escape of the foul air. The entering air must not be too cold, and must not produce a draught, but should be distributed equally, as far as possible, to all parts of the room.

§ 17. **Natural Agents of Ventilation.**—The property of the *diffusion of gases*, by means of which every gas fills the whole of the space in which it is, tends to make the composition of the air uniform, but the air is not changed by it, and it does not in any way affect the suspended matters in the air. The wind is a

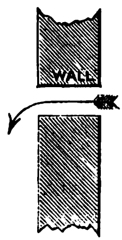
very powerful agent of ventilation, and even a wind which is so slight as to be imperceptible—travelling, say, at the rate of a mile an hour—will change the air of a building completely if the windows are open on both sides of it. The great objection to depending on the wind as a ventilating agent is its irregularity. Although the air is seldom quite still, it frequently moves too fast to be utilised advantageously for the purposes of ventilation, especially in cold weather. The direct action of the wind is utilised in Sylvester's plan, which consists in having a large cowl, which always turns towards the wind, so that the wind blows into it, placed at a short distance from the building to be ventilated, with the basement of which it is connected by an underground channel, along which the wind blows into chambers, whence, after being warmed by contact with stoves, it escapes into the rooms above. It is in this way also that the holds of ships are commonly ventilated. The wind also acts *indirectly* as a ventilating agent. As it passes over the tops of chimneys it produces a diminution of pressure in the air in the chimney (for a current of air always produces a diminution of pressure in the air in its vicinity), and so an up-draught is caused in the chimney, or the up-draught produced by the fire is increased. The little bottles by means of which scent is dispersed into the air by blowing through a horizontal tube across a vertical one which dips into the scent in the bottle, and Dr. Richardson's ether-spray apparatus, are constructed upon this principle. This is one reason why there are frequently down-draughts in chimneys the tops of which are protected from the

action of the wind by the vicinity of some higher building, and why the chimneys of a house require to be higher than the surrounding buildings; although the chief reason for smoky chimneys is that there is not sufficient provision allowed for the supply of air to the fire, and so air comes down the chimney for that purpose, and forces smoke before it into the room. Cowls are sometimes used to prevent down-draughts. Fixed cowls are better than revolving ones, as they are much less likely to get out of order. On the other hand, all such contrivances are apt to get clogged with soot, and require to be cleaned from outside, so that the use of them is better avoided if possible.

The most important agent that we can utilise in natural ventilation—that is to say, in ventilation which is effected without the use of apparatus for forcing the air in one direction or another—is found in the movements which are produced in the air by *variations in its weight due to differences in its temperature.* In the summer when the air is warm outside we do not, as a rule, require any contrivances to secure ventilation, as we can open all the windows and doors and get the air of the house changed rapidly, unless the air happens to be almost perfectly stagnant; and so in the following pages we shall always assume that the air outside is cold and that the air inside the rooms is warmed by the presence of human beings and sometimes by fires. Warm air is light, and the cold air outside, being heavier and exerting a greater pressure than the air inside the room, will force its way in through any opening that is made. Since the air outside which we wish to introduce is heavy, and

the air inside which we wish to get rid of is light, and moreover since the air at the upper part of the room is more impure than at the lower, owing to the fact that the air expired and the products of combustion of candles, &c., are warm and light, and therefore ascend to the top of the room, it would at first sight appear that we ought to admit air low down in the room and to have a place for its exit near the ceiling. But cold air cannot be admitted near the floor of a room as it rushes in with a considerable force causing a draught. If, on the other hand, an opening is made straight through the wall into the external air above the heads of the people in the room, the cold air will pour in and fall down in a stream at a short distance from the opening, and therefore it is necessary to give the air coming into rooms from the outside an upward direction, so that it shall come into the room like a fountain and not like a cascade. When this is done the cold air coming in rises up towards the ceiling of the room and is gradually mixed with the warmed air and becomes warmed itself, and so the temperature of the room is prevented from becoming either too hot or too cold, and the impure air is continually diluted with large quantities of pure air.

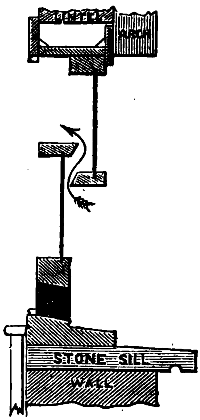
Fig. 1.



§ 18. **Methods of Ventilation.**—We will now, bearing this principle in mind, consider the various ways of admitting fresh air into dwelling-rooms. If we open an ordinary sash window at the bottom, the air comes in too low down and is not directed upward, and if we

open it at the top, the air that comes in pours down upon the heads of the people in the room. By placing a block of wood beneath the lower sash, running from side to side, so as to prevent the air coming in below the lower sash when the latter is shut tightly down upon it, the woodwork of the two sashes is separated in the middle of the window, and the air comes in between the two sashes at this point and is directed upwards by the top part of the lower sash. This plan, which was suggested some years ago by Mr. Hinckes Bird, is the simplest for the admission of outer air into dwelling-rooms, and is one which is particularly well suited for bed-rooms, and for its cheapness well adapted to the wants of the poor. The disadvantages that attach to it are that in large towns blacks are brought in with the entering air, and that the window looks as if it were not shut and makes nervous people apprehensive of draughts. But these disadvantages are more than counterbalanced by the great advantage of the simplicity of the plan, and all attempts for preventing dust from coming in merely result in obstructing the entrance of the air. Sometimes instead of placing a block of wood beneath the lower sash, the lower bead of the window frame is made deeper, so that the lower *sash can be lifted* up for about a couple of inches with-

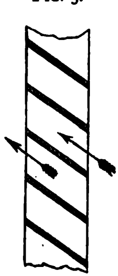
FIG. 2.



Hinckes Bird's plan of ventilation by sash window. A, block under lower sash.

out any air coming in beneath it, and yet so as to allow air to enter between the meeting rails in the middle of the window, as shown in Fig. 2. Small windows hung on centres are sometimes used in lobbies and passages: these also give the air an upward direction. Where Venetian blinds are used, when the window is open at the top and the laths of the venetians inclined upwards, most of the air that comes into the room is given an upward direction. What are called Louvre ventilators very much resemble these blinds in their construction; they are sometimes fixed, with the louvres parallel to one another all directed upwards, and are useful in many instances where it is necessary that the ventilators should be permanently open, as in stables, cow-sheds, slaughter-houses, &c. Sometimes the louvres are movable, as in Moore's ventilator, which is constructed of slips of glass, mounted in a metal frame in such a manner that they can be separated from one another, or brought together so as to close the ventilator, by pulling a string. This ventilator is intended to replace one of the window panes. It answers its purpose very well, but the joints require to be well oiled, or they are liable to get rusty and to prevent the working of the contrivance—especially in the atmosphere of a large town. In French windows which open in the middle like folding doors, the best plan is either to have the glass above the window or *the upper part* of the window itself made to swing on *a hinge at its lower* part so that it can be opened to

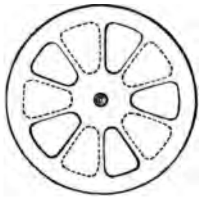
FIG. 3.



Louvre Ventilator.

any desired angle. In such cases and also in large sash windows, Cooper's ventilators are very frequently used. They consist of a circular disc of glass with five oval apertures in it, which works on a pivot through its centre in front of and close to one of the panes of glass of a window. In this pane there are five similar holes pierced. It follows, therefore, that when the disc is turned so that the holes in it are opposite those in the window, the air will get through them, and when it is turned so that the holes in it are opposite to the glass between the holes in the window pane, the air is prevented from entering. The chief advantage of this ventilator is that it has no parts made of metal and so does not get out of order or rust, and that is doubtless why it is so largely used, notwithstanding the fact that it does not give the entering air an upward direction. For small rooms and closets, windows swung on their centres, the upper half sloping inwards and the lower outwards, are very effective ventilators. The most suitable windows for large rooms, as assembly rooms, &c., in which great numbers of people congregate and where immense volumes of air are required, are windows composed of several sashes which do not slide up and down, but slope forwards into the room when they are opened so as to form an opening of very large area, and at the same time to give the entering air an upward direction.

FIG. 4.



Cooper's Ventilator.

Air may also be admitted into a room, either

directly from the outer air or from a hall or staircase, by making a hole through the wall, high up, but not too near the ceiling. The air which enters must be given an upward direction by means of a piece of board fastened against the wall below the hole, and making an angle with the wall. This piece of board should also be provided with side pieces or cheeks, and then the air as it enters strikes against this slanting board and is given an upward direction towards the ceiling, where it mixes with and is warmed by the air in the upper part of the room. If the opening be placed too near the ceiling, the air strikes against the ceiling with considerable force, and then falls downwards with sufficient velocity to cause a draught on the opposite side of the room. It is usual to place wire gauze or perforated zinc on the outer side of these openings, partly with the view of arresting blacks, &c., and partly in order to divide the cold air into a large number of small currents, which are more readily warmed as they enter the room. This perforated zinc gets very dirty and so an iron grating is better. The Sherringham valve admits air in precisely the same way, only that the valve itself is movable, and not fixed like the sloping board just mentioned. There is an iron box which fits into the hole

FIG. 5.

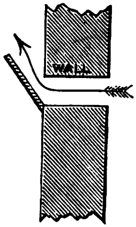
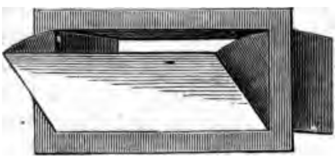


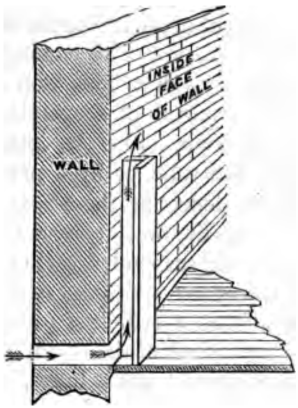
FIG. 6.



Sherringham Valve.

cut in the wall, and has in front of it an iron valve, hinged along its lower edge so that it can open towards the room. The valve has cheeks attached to its sides, which fit into the box when the valve is shut. A heavy piece of iron presses against the back of the valve inside the box, and tends always to keep the valve open. By means of a string attached to it and passing round a pulley the valve may be closed at will, or partially closed, and a weight attached to the end of the string, and serving as a handle, just balances the weight of the valve and the piece of iron behind it, so that the valve will remain in any position in which it is placed. In a large room it is better to place several small or moderately sized valves at different parts of the room, but not opposite to one another, than to have one large one, as the body of cold air entering by one large valve is almost sure to cause a draught somewhere. If the valves are placed opposite to one another, much of the air which enters at one or more goes straight out at the others.

FIG. 7.



Vertical Tube Ventilator.

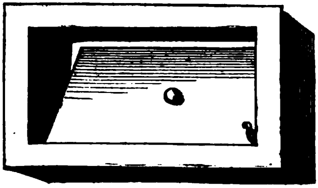
The system of vertical tubes introduced by Mr. Tobin affords an excellent method of admitting fresh air into rooms, and in

what we have seen to be the correct way, viz. in an upward direction. Horizontal tubes are placed near to or below the floor, and open through the wall into the external air. To these, vertical tubes (5 or 6 feet high) are attached, and open at their upper ends freely into the room. The pressure of the outer air is sufficient to cause it to rise through these tubes into the room in a vertical current, which is clearly defined for some distance above the top of the tube, so that while a candle held over the tube is immediately blown out, when it is held just outside the current of air its flame is scarcely perceptibly affected. Higher up, the current of cold air separates out like a fountain, and mixes, as before described, with the air of the room. No draught whatever is caused by these tubes unless they are placed so that the current of air is interfered with by projections, &c., and the amount of air coming in may be controlled by means of a valve. This plan also affords great facilities for the removal of suspended substances, soot, &c., from the air, either by placing a long muslin bag inside the tube, or by a patented device which consists in deflecting the air as it enters the horizontal tube from the outside upon a surface of water in a tray, so that the suspended particles fall into the water.

Generally speaking, in dwelling-rooms the chimney affords a sufficient escape for foul air and forms the exit shaft of the room, though it may not be sufficient if much gas is burnt, unless the products of its combustion are carried away by special tubes. Dr. Neil Arnott, considering that the warm foul air accumulated near the top of the room, devised a valve

by which it could be allowed to pass directly from the upper part of the room into the chimney flue. An opening was made through the wall near the ceiling into the chimney, and an iron box placed in it in which was a light metal valve capable of swinging towards the chimney flue, so as to allow a passage of air from the room into the chimney whenever the pressure of the air in the upper part of the room was greater than that in the chimney, but incapable of opening towards the room, so that whenever there was greater pressure in the chimney the valve was shut. Unless very well made and carefully padded, these valves are apt to make an irregular clicking noise, which is very disagreeable, and whenever they get out of order they admit blacks and air from the chimney flue. The noise is lessened by a modification of this valve known as 'Boyle's Valve,' in which, instead of there being one light metal valve, there are several small flaps of talc which are hung in front of holes in a metal plate, so that they can, like Arnott's valve, open into the chimney, but not into the room. A much better plan than either of these is, however, to have a separate shaft running by the side of the chimney flue, and having an opening into each room near the ceiling. The air in this shaft gets heated and rises, and air is drawn into it from the upper part of the

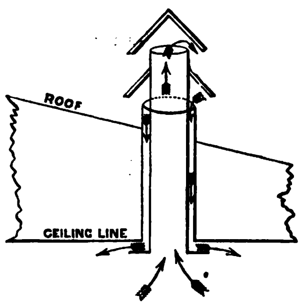
FIG. 8.



Arnott Valve.

rooms with which it communicates. Where gas is burned and a special tube is provided to carry away the products of combustion, either this may be large enough to act as an exit shaft for the air of the room, or, as is the case with sunlight burners now used for lighting large rooms, a shaft placed round the tube which carries off the products of combustion and opening into the upper part of the room may be contrived for this purpose; and in a large building, lecture room, or theatre, tubes may be constructed to carry the products of combustion of each gas burner into this shaft and so increase the upward current of air inside. By these means each gas burner is made to help in the ventilation of the room instead of helping to render the air impure. In the McKinnell ventilator, which is very well suited for small rooms having no rooms above them, there are two tubes, one inside the other, which pass through the ceiling into the outer air. A rim is placed round the lower end of the inner tube at a short distance below the ceiling and parallel to it, while the upper end of this tube is carried higher into the air than the upper end of the outer tube. The heated air of the room then escapes through the inner tube (and this escape is much facilitated if a gas jet be placed

FIG. 9.



McKinnell Ventilator.

beneath it), while fresh air enters between the two tubes and is given a direction parallel to the ceiling by the rim round the end of the inner tube, so that it does not fall down too directly into the room. A cover has to be placed a little above the tubes to prevent the rain coming in, and it has to be arranged so that the air cannot go out at one tube and be blown back into the room through the other. It is upon the principle of this ventilator that railway lamps are made. The products of combustion of the gas, or oil, pass out through a tube in the middle of the reflector, which answers to the rim of the inner tube in McKinnell's ventilator, and air comes in to supply the flame between the reflector and the top of the lamp.

In large buildings where hot-water pipes are used for warming purposes, the air entering the rooms may be warmed by passing coils of this pipe round the tubes through which the air is admitted; and by enclosing the vertical pipes which run from a boiler in the basement to the top of the house in a shaft communicating by openings with the upper part of the rooms on each floor, the foul air may be drawn out of the rooms as in the plan proposed by M. Léon Duvoir.

§ 19. **Artificial Ventilation.**—In some cases, in large crowded buildings, none of the above plans are sufficient to ensure a constant supply of pure air, and so it is necessary to resort to what is called 'artificial ventilation,' in which the air is driven in certain directions by machinery.[1]

[1] Sometimes the methods of extraction by heat are included

Artificial ventilation is of two kinds: (1) ventilation by aspiration, in which the foul air is drawn out of the building by machinery, and fresh air allowed to come in to take its place after having been previously warmed, if need be; and (2) ventilation by propulsion, in which fresh air is driven into the building and foul air allowed to escape by shafts, or, still better, by flues. In each case wheels having metal vanes on their axles, and called fans, are used. They are made to revolve at an immense rate by stationary engines or by any motive power, and by means of them air can in the one instance be drawn out of the building, or, on the other hand, it may be forced through tubes into it. These plans are in use at various hospitals and large buildings, and each has its advocates. It appears, however, generally speaking, that the plan of ventilation by aspiration is on the whole the cheaper and more effective of the two, but that where expense is no object the plan of ventilation by propulsion, especially if aided by the extraction of the foul air by means of a flue, affords a method of accurately controlling the amount of air and its condition as to suspended matters, moisture, temperature, &c., so that by it air can be delivered, as is done in the Houses of Parliament, in sufficient quantity, freed from suspended matters, and warm or cold, dry or moist, as occasion requires.

under this head, but I have preferred to refer to them under 'Natural Ventilation.' Openings through which air comes into a room should be made altogether as large as those through which it goes out, and the area of the openings should be equal to about 24 square inches for each individual in the room. No single ventilating opening should be larger than a square foot; in ordinary rooms much smaller ones are desirable.

CHAPTER IV.

FOODS.

§ 20. **Foods Classified.**—Food is required for two purposes: (1) *to replace the losses* that are continually taking place from the body through the organs which separate waste substances from the blood; and (2) *to supply the warmth*, or 'animal heat,' which is necessary for life. The *food substances* are best divided into two great classes: (*a*) the INORGANIC, or those belonging to the mineral kingdom; (*b*) the ORGANIC, or those belonging to the animal and vegetable kingdoms. The inorganic food substances are water and mineral salts. The organic food substances are divided into two sub-classes: (*a*) those which contain no nitrogen, and are therefore called the *non-nitrogenous* or non-azotised foods; (*b*) those which contain nitrogen, and are called the *nitrogenous* or azotised foods.

§ 21. **Inorganic Food Substances.**—(A.) **Water.**—Water is contained in all the tissues. About two-thirds of the weight of the body consists of it. It is separated from the blood continually by all the excretory organs to the amount, on the average, of 50 ozs. by the kidneys, 18 ozs. by the skin, and 9 ozs. by the lungs in 24 hours; and so water is necessary to our existence, and life can be maintained for a much longer period during starvation if water be given than if it be withheld. The further consideration of drinking-water is reserved for another chapter.

(B.) **Mineral Salts.**—The most important of these is common salt, which is not merely a condiment but a

necessity for our existence and for the existence of animals generally. It is contained in all the tissues, and is an essential constituent of the blood. Salt is procured in some countries from the sea-water, either by freezing it, as in Norway, and continually removing the ice, which contains little or no salt, or by concentrating it by spontaneous evaporation and allowing the salt to crystallise from the strong brine left. It is also obtained from salt lakes and salt springs in various parts of the world; and lastly it is found in large quantities in the solid state, in which it is called rock-salt, in some rock-formations, from which it is obtained either by mining, or by boring and pumping out the brine which collects in the bore-holes, evaporating the water off, and allowing the salt to crystallise. Other important salts are the phosphates, especially that of lime, which is required particularly for the bones—we get these in small quantities in many of our foods, but chiefly in bread. Salts of potash are contained in the blood and in most of the tissues, and are supplied to us chiefly in the vegetables that we eat. Salts of iron are also an absolute necessity of life, as the colouring matter of the red blood corpuscles contains iron, and this substance is supplied in small quantities in almost all our foods. Many other mineral salts are contained in our foods, but need not be specially alluded to.

§ 22. **Organic Food Substances.—(A.) Non-Nitrogenous.**—There are two important divisions of the food substances which do not contain nitrogen, and *some few substances* which do not come under either *division.* *These* are (1) the *fats and oils*; and (2)

the *carbo-hydrates*, including sugars, starches, gums, &c. Besides these two divisions alcohol and certain vegetable acids come under this head.

(1) *The fats and oils.*—These consist of carbon and hydrogen, with a little oxygen, and are derived from both the animal and vegetable kingdoms. When eaten they are not affected by the saliva in the mouth nor by the gastric juice in the stomach, but when mixed with the bile and pancreatic juice in the small intestines they become divided into an exceedingly large number of very small particles, which are uniformly spread through the semi-liquid mass of digested food. These small particles of fat pass bodily through the walls of the little villi or projections from the mucous membrane of the small intestines into the lacteal vessels, which begin there, and give the fluid in those vessels (the chyle) its milky appearance. They are then conveyed through the thoracic duct in the mixture of lymph and chyle into the blood in the great veins, which blood is going to the right side of the heart, to be pumped by the right ventricle through the lungs, whence it passes into the left auricle, and so into the left ventricle, which pumps it through the arteries into the capillary vessels in the tissues of all parts of the body. The particles of fat in the blood partly go to supply fat for the various tissues of the body which contain it, and they partly go to produce animal heat in the following way:—The oxygen which is received into the blood through the lungs is capable of combining with the carbon and hydrogen in the fat, forming ultimately carbonic acid with the carbon, and water with the hydrogen. These combinations are

attended with the production of heat (as occurs in most cases of chemical combination), so that the fat in our food is partly used as nourishment to the body, and partly for the production of animal heat. It is also important as an aid to the proper assimilation of other foods, so that the body is not well nourished by the food if fats are absent from it, and the system soon gets out of order; and lastly fats aid the excretory power of the intestinal canal.

(2) *The carbo-hydrates.*—These consist also of carbon, hydrogen, and oxygen, but they contain a large proportion (about half their weight) of oxygen, and the oxygen and hydrogen are in them in the proportions in which they are in water, viz. eight parts of oxygen to one of hydrogen by weight; so they might all be looked upon as if they were compounds of carbon and water, and this is why they are called carbo-hydrates. Cooked starches, gums, and the various kinds of sugar are all changed by the action of the saliva in the mouth into a form of sugar called grape-sugar. If any parts of them escape this action (which takes place in the mouth and during the passage of the food into the stomach) they are not further acted upon in the stomach, but the change of starch, &c., into sugar goes on again in the small intestines by means of the pancreatic juice, which is very much akin to saliva. The grape-sugar dissolved in water passes through the walls of the small intestines into their blood-vessels, and so gets into the blood in the veins which go to form the portal vein—the great vein which enters the liver. This blood then contains sugar; but neither the blood that leaves

the liver, by the liver vein, nor the blood in the general circulation in the body, contains more than the smallest traces of sugar, and whenever in disease sugar appears in the blood it is separated from it as a waste substance by the kidneys, so that the sugar which is brought to the liver in this portal vein is disposed of somehow. The liver prepares from it a substance called 'liver starch,' and then, in a way not at present clearly explained, is able from this to produce fat, and this is no doubt the chief function of the liver—the bile being really a residuary product. This fat is then disposed of in the economy in the way mentioned before, and it is practically found that all animals fed upon food containing much starch or sugar become fat, and without exercise may become exceedingly fat. It is with such food that fowls, geese, &c., are fattened for the market.

Accordingly the first function of these two great divisions of the non-nitrogenous foods is to supply heat by their oxidation in the blood, and this is their most important function; and the second is to supply fat to the various tissues of the body.

The first division, that of the fats and oils, is more important than the second, that of the starches, &c., and animals bear deprivation of the latter much better than of the former. This is mainly due to the important aid that fats afford in the assimilation of foods. No mixture of these non-nitrogenous foods is capable of keeping up the life of an animal, because the waste substances contain nitrogenous matters which require to be replaced, and consequently foods

containing nitrogen are necessary for life. These we shall now consider.

(B.) **Nitrogenous or Azotised Food Substances.**—There are two special divisions of these: (*a*) gelatine and the allied bodies; (*b*) albumen and other kindred substances, sometimes called the 'Protein' bodies.

(*a*) *Gelatine.*—Gelatine contains carbon, hydrogen, oxygen, nitrogen, and a trace of sulphur. It is prepared in various ways, commonly by boiling bones, and has long been considered to be a valuable food substance. It is very easily digested in the stomach and absorbed into the blood. Not being excreted as gelatine, it is clear that it must be disposed of in the economy in some way or other. Animals will not live on it alone, nor on mixtures of it with non-nitrogenous substances, and so it was concluded some time ago that it had no nutritive value, and that the practice of giving jelly to invalids was useless. It has since been clearly shown by experiments that animals which are fed upon a diet insufficient to replace the losses of nitrogenous substances from their bodies will thrive if gelatine be added to this diet, and so it is certain that it is able to do part of the work of nitrogenous food in the system. It appears probable that it is not capable of forming nitrogenous tissues, but that it is capable of taking the place of part of the nitrogenous substances in the blood which undergo oxidation, and so is valuable, especially to those who are incapable of digesting more highly nitrogenous foods, as it prevents their tissues from wasting so fast.

(*b*) *Protein compounds.*—The more important of these are albumen, contained in many of the animal

and vegetable foods; fibrin and syntonin, contained in meats; casein in milk; gluten in the grains of cereals; and legumen in beans, peas, &c. They contain carbon, hydrogen, oxygen, nitrogen, and a little sulphur or phosphorus. They are not acted upon by the saliva in the mouth, but are dissolved by the gastric juice in the stomach, the result being what is called 'a peptone.' They are absolutely necessary to the existence of all animals; their first function being to replace the various tissues of the body which are continually being wasted, and their second to help in the production of animal heat.

It was long supposed that the force exhibited by the exercise of parts of the body was due to the oxidation of nitrogenous matter in the tissues—especially in the muscular tissue—such oxidation being attended with the production of heat, which was converted into muscular force; but it has now been shown conclusively that the excretion of waste nitrogenous substances is not proportional to the amount of exercise taken, as would be the case if this were true; but that, on the other hand, it is the excretion of carbonic acid and of water, which increases proportionally to the amount of exercise, and a very large amount of work has been done for a time with foods containing no nitrogen. It is certain, therefore, that it is the oxidation more especially of the non-nitrogenous substances in the blood that is the source of animal energy, and that the nitrogenous matters in the food are especially used for building up the tissues, which are wasted during the process; the tissues containing nitrogenous substances, and especially the muscular tissues, being in fact the apparatus by

means of which the energy generated by the oxidation of the non-nitrogenous food in the blood is utilised. As this apparatus wears out by use, so it requires continually to be replaced; and this is why those who take much exercise require a larger quantity of highly nitrogenous food, although the work they do is mainly the result of the oxidation of non-nitrogenous substances, of which they require a largely increased supply.

§ 23. **Other Food Substances.**—Food substances which do not come under either of the above important heads are, among non-nitrogenous bodies, alcohol, certain vegetable acids, as the citric, malic, and tartaric, various ethers, &c.; and, among nitrogenous bodies, the essential alkaloids of tea, coffee, cocoa, &c. The vegetable acids above mentioned are, for some reason or other, necessary to our healthy existence, and the absence of these acids, and especially of their potash salts, from the food is always attended with the production of scurvy. For this reason it is necessary for those who make long voyages to be supplied with substances containing these acids, as, for instance, lime-juice.

Alcohol is a substance containing carbon, hydrogen, and oxygen, which is certainly oxidised in the blood as only the merest traces of it are found in the excretions, although a considerable quantity be given with the food. It does not appear, however, that when alcohol is taken with the food the heat of the body is increased. On the contrary it is in many instances diminished; and this can only be explained, since the oxidation of the alcohol itself must be attended with the production of heat, by supposing

that in some way or other the presence of alcohol in the blood prevents the oxidation of other substances, and so ultimately lessens the production of animal heat. Alcohol cannot, therefore, be said to be a food substance properly so called, as it certainly does not contribute to the formation of the tissues of the body, nor, although it is oxidised in the blood, does it assist in the production of animal heat and muscular energy. In moderate quantities it acts as a stimulant and excitant of the nervous system, but in larger ones as a depressant and narcotic.

The alkaloids of tea, coffee, and cocoa cannot by themselves be considered to be nutritive substances. They act as important stimulants of the nervous system, and are valuable in aiding recovery from exhaustion, whether caused by mental or bodily exertion. They are not necessary to the life of an animal any more than alcohol is, but they are valuable, especially in counteracting the immediate evil effects of over-work, and it is a very remarkable thing that plants which have been used for ages in various parts of the world for preparing decoctions to drink should have been found to contain either the same esssential alkaloid, as in the case of tea and coffee and some other less-known plants, or one nearly allied to it, as is the case with cocoa.

The effects of the various alcoholic drinks, and of tea, coffee, and cocoa, will be considered further on.

§ 24. **Milk and Eggs.**—A complete diet contains all the food substances mentioned in sections 21 and 22 in their proper proportions: the only food which fulfils *this condition*, and which is therefore capable of keeping

up the life of an animal for any length of time by itself, is milk, the food upon which all young animals of the class mammalia (the animals which nourish their own young) depend entirely during a certain portion of their existence. The milk of various animals differs somewhat in composition, but it always consists of certain solid substances, either suspended or dissolved in water. These are (1) nitrogenous substances, especially casein which forms the curd; (2) non-nitrogenous substances of both kinds, viz. fats which are suspended in the water in the form of very fine particles, and lactose, or sugar of milk, which is dissolved in it; (3) mineral salts such as are required for the nourishment of an animal, especially phosphate of lime, chloride of sodium or common salt, salts of potassium, magnesium, iron, &c.; and (4) water. Milk thus contains all the food substances. Cow's milk contains on an average 87·5 per cent. of water and 12·5 per cent. of solids, of which a little over 3 per cent. consists of fat. It has a density of about 1,030, taking water as 1,000. When allowed to stand a large proportion of the globules of fat rise to the surface, forming the cream. The quality of milk may be roughly ascertained by means of the lactometer, an instrument for showing the density of milk; and the creamometer, an instrument for showing the percentage of cream that rises when the milk is left to stand. If the lactometer shows a density several degrees less than 1,030, and at the same time less than ten per cent. of cream rises in twelve hours in the creamometer, water has almost certainly been added to the milk. The indications of these two instruments when taken together give a

very good idea of the quality of a sample of milk, although neither of them taken by itself can be relied upon to do so. After milk, the nearest approach to a complete food is the egg of a fowl, the white of which is almost pure albumen, while the yolk contains a large percentage of fat and a considerable quantity of albumen as well. The percentage of water and of salts (the shell being excepted) is too small, and there are no starches or sugars. The want of salts is made up for, while the chick is being formed inside, by the solution of the shell, and the insufficiency of heat-forming substances is supplied by the process of incubation. The yolk is highly valued as a nutritious food, the large proportion of fats which it contains being in a very digestible form. The white is a very digestible form of albumen, when raw or when slightly cooked, but when cooked so long that it becomes hard it is attacked by the gastric juice with much greater difficulty and is therefore more indigestible. When eggs are kept, they lose weight by transpiration of water through the shell which is very porous. Air passes at the same time through the shell into the egg, and after a time, in the presence of this air, decomposition of the albumen takes place, and the egg ultimately, without the shell being broken, becomes rotten, the sulphur in the albumen forming sulphuretted hydrogen gas, which gives to rotten eggs their peculiar smell. In a solution of brine containing one ounce of salt in half an imperial pint of water, fresh eggs will sink whilst stale ones will float, and rotten eggs become so light that they will even float in fresh water. Eggs may be preserved for almost any length

of time by keeping them in brine, or, still better, by thoroughly smearing them over with lard or butter.

§ 25. **Animal Foods.**—The flesh of animals affords a highly nitrogenous food, and with the addition of water is sufficient to keep up life for a long while. The flesh of all animals in a healthy state, except a very few poisonous ones, is good for food. The muscular parts form, generally speaking, the best food, but most of the viscera are also eaten as delicacies. Animal foods are commonly divided into red meats and white meats. Red meats form a highly concentrated food containing a large percentage of nitrogenous substances. The chief of them are the flesh of oxen, sheep, pigs, &c., of most game and wild fowl, and of salmon. They differ very much in their digestibility, mutton being the most digestible and best suited for invalids; the flesh of wild fowl, on the other hand, being hard and indigestible. The flesh of young animals, as veal and lamb, is not so digestible as that of more mature ones. Flesh is more nutritious if eaten raw than when cooked, but less digestible. In cooking a joint the object should be to keep in it as much of the nutritious matters as possible. This can be done by hardening the surface by exposing it to the heat of a blazing fire, or by plunging the joint into boiling water and then afterwards cooking it at a more moderate heat. If, on the other hand, it is desired to make a nutritious broth or soup, the meat should be cut into small pieces and placed in cold water, which should then *be simmered*. By this means the largest possible *percentage of soluble* nutritious matters is extracted

from the meat. Bones are useful for preparing soup, from the amount of gelatine they yield when boiled, and the use of soup at the beginning of dinner is to be recommended because it contains so much dissolved nutriment which can be absorbed at once into the blood and enable it to secrete good gastric juice.

§ 26. **Preservation of Meat.**—Meat is commonly preserved by steeping it in brine. By this means, however, a large portion of the soluble nutritious matter of the meat is dissolved out of it, and the meat itself is hardened and rendered less digestible. It is also preserved in large quantities in air-tight cases in the following way:—The cases are packed with the pieces of meat and filled up with gravy and then closed with a cover which is hermetically sealed all round except at one point. They are then exposed to a heat above that of boiling water for some hours. By this means all the air contained in them is driven out and all living germs destroyed. The aperture is now soldered over while steam is still escaping from it, and if the operation has been successfully performed so that every particle of meat in the tin has been exposed to the required temperature, the meat will keep good for any length of time. If, on the other hand, the tin is not hermetically sealed, so that air can get into it, or if the smallest portion of the meat has not been heated to the required temperature, the meat will go bad and the living things which always accompany putrefaction will appear in it. Meat may also be preserved by cold—a method which will no doubt be largely employed in the future as considerable quantities of meat are now

brought over from the United States weekly in cooled chambers. Another method of preserving—not much employed for meat although largely for fish—is that of drying. If meat be sufficiently dried by the heat of the sun, or otherwise, it can be preserved for a long time. Thus we see that the methods for preventing putrefaction of meat—that is to say for preventing its going bad—are (1) the use of substances such as common salt, called antiseptics, which are found to prevent such changes; (2) a sufficient temperature to destroy life, accompanied by some means of preventing the access of air, which always contains suspended in it living germs that are capable of setting up putrefaction; (3) a sufficiently low temperature; and (4) deprivation of moisture.

Of the preparations made from meat, Liebig's extract contains but a small proportion of the nutritious nitrogenous substances which make meat so valuable a food, and it must be regarded rather as a flavouring material for soups, for which it is well suited, than as a food in itself. The preparation known as 'fluid meat,' on the other hand, is meat which has been subjected to a process of artificial digestion, and contains the nutritious substances of the meat in a concentrated form.

§ 27. **Diseased Meat.**—It is illegal to expose for sale the meat of animals which have died a natural death or which have been killed because they were diseased; and rightly so, because such meat is more liable to decomposition than the meat of *healthy animals* which have been killed, and the *ting of decomposing* meat is liable to produce

disorders of the digestive apparatus and a condition of the blood which leads to the eruption of boils on the skin. It has not, however, been shown that any harm arises from eating the meat of animals which have died a natural death, if it has been well cooked. The flesh of animals sometimes contains little bodies which are the immature condition of some of the parasitic worms from which human beings suffer. Such flesh ought not to be eaten, because the little bodies contained in it will develop themselves into tape-worms in the intestinal canal, or into other forms of parasitic creatures. Nevertheless, if the meat be thoroughly well cooked, there is little danger, and in some countries it is necessary to eat such meat as almost all the animals are diseased in this way. One of these parasitic worms, which is fortunately very scarce in this country, is very dangerous to life and produces a painful disease accompanied by high fever. It is called the trichina spiralis, and infests the muscles of persons who eat uncooked meat containing it. It is chiefly got by eating uncooked sausages.

§ 28. **White and Red Meats.**—White meats contain a smaller percentage of nitrogenous substances than the red ones, and are therefore less nutritious. They are, however, as a rule, more digestible, and so are well suited for invalids. The flesh of the common fowl and turkey are examples among birds. The flesh of reptiles, as that of the turtle (which is esteemed an article of luxury), of the batrachia as frogs, and of fishes except the salmon, *of crustacea* as of crabs, lobsters, shrimps, &c., of

molluscs as oysters and mussels, and even of lower animals as sea-anemones, is included under this head. The flesh of most fish is very digestible, the chief exceptions being fish like the mackerel and eel, in which the flesh contains a considerable proportion of fat. Generally speaking, the flesh of fish is more digestible when boiled or broiled than when fried, on account of the fat used in the latter process. The flesh of crabs and lobsters is too hard and closely packed to be easily digested, while oysters if eaten raw are exceedingly digestible, though when cooked they form a hard leathery mass which resists the action of the gastric juice. Mussels, for some reason or another, occasionally have poisonous qualities, and the eating of almost any shell fish in excess is apt to produce disorders of the digestive apparatus, frequently accompanied with nettle-rash on the surface of the body.

§ 29. **Butter and Cheese.**—Butter is prepared by separating the fatty particles from milk by churning. It is a very digestible form of fat, and is eaten with foods which themselves do not contain sufficient fat. When well made it contains very little casein, or curd of milk, and the less curd it contains the longer will it keep sweet. It is preserved for a considerable length of time by mixing salt with it, but fresh butter may be kept sweet in hot weather by keeping it under water which is frequently changed. Buttermilk, the residue from the preparation of butter, is a very nutritious substance, containing everything in the milk except the fat. It were well if it were used as an article of food by the poor in country places much more than it is.

It forms a valuable diet for invalids who are unable to digest fat, and for children suffering from wasting diseases. Butter is often fraudulently mixed with other fats; but these, although nutritious substances, are less digestible than butter, and therefore less suitable for the purposes for which it is used. Cheese is made by warming milk and then adding a little acid or else a piece of rennet, by which the casein is coagulated or rendered insoluble. This and the fat are then separated from the liquid part or whey by straining, and the mixture of curd and fat put into moulds and dried by pressure. The varieties of cheese chiefly depend upon the proportions of fat contained in them. The poorest kinds, which are very hard (as Dutch cheese) are difficult of digestion, and are made from skimmed milk. Those of medium quality—the ones most commonly used, as Cheshire, &c.—are made from unskimmed milk; while to make the richest cheeses, such as Stilton, cream is added to the milk. Cheese is highly nitrogenous, but difficult of digestion, the softer kinds being the more digestible. Toasted cheese is an extremely indigestible substance, able to resist very completely the action of the gastric juice. Cream cheese consists chiefly of curd which has not been pressed. It is much more digestible than harder forms of cheese. Many varieties of cheese are made from goats' milk, and retain the peculiar flavour of that milk.

CHAPTER V.

FOODS (*continued*).

§ 30. **Vegetable Foods.—Bread.**—The most important of these are derived from the grains of the *cereals*. These grains contain a large quantity of starch, some nitrogenous substances, one of which, called 'gluten,' is peculiar to them, and mineral salts, especially phosphate of lime. The grains are ground, and so the various flours or meals produced. The outer coatings of the grains are sometimes removed first, and form bran. This contains a large proportion of nitrogenous substances and salts. The interior part of the grain contains less of these, and consists chiefly of starch. When it is ground repeatedly it forms the white varieties of flour. Bread is made from such of these grains as contain gluten—notably from wheat and rye. The flour is made into a paste with water, and it is the gluten—a sticky substance—that enables this to be done. The paste is then rendered light by causing it to be permeated with bubbles of gas, produced in one of three ways—either by fermentation, set up by the presence of yeast, or by baking powders, which consist of mixtures of carbonate of soda and tartaric or citric acid, and which give off carbonic acid gas when mixed with the wet dough, or by actually forcing carbonic acid into the paste as in a preparation known as aërated bread. By these means the dough is rendered 'light,' and the bread baked from it digestible. New bread is not easily digested, because it forms a

pasty mass in the mouth, and so the starch in it is not readily attacked by the saliva, whereas stale bread and toast, rusks, biscuits, &c., which are crisp and readily broken into fragments by the teeth, are easily digested, as those fragments are readily attacked by the saliva. Brown bread is prepared from whole flour containing the bran from the outer layers, as well as the inner part of the grain. It is less digestible than white bread, since the bran, although it contains a large proportion of nutritious substance, contains also a great deal of indigestible matter, and is not readily attacked by the gastric juice. It acts rather as a mechanical stimulant to the coats of the stomach and intestinal canal than as a nutritious article of food. The harder kinds of wheat, as Sicilian wheat, containing much gluten, are used for the preparation of macaroni—a highly nutritious but somewhat indigestible food. Oats, although they contain very little gluten, contain a large proportion of other nitrogenous matter and of fat. They cannot be used for making bread, but form an important article of diet in some countries, notably in Scotland, and are also largely used for the fattening of horses. Maize contains a very large proportion of fatty and of nitrogenous matters, and forms a very nutritious food. Rice, on the other hand, contains a smaller amount of nitrogenous substance than any other cereal grain, and is the least nutritious of them all. Where it is eaten as the staple article of food, as in India, it must be mixed with milk, and cheese, and other nutritious substances. Alum and other substances are sometimes mixed with flour to make the bread look whiter. This is an injurious practice, as

such bread is less nutritious, and is liable to cause disorders of the digestive organs.

§ 31. **Other Vegetable Foods.**—The seeds of beans, peas, and lentils contain a very large proportion of nitrogenous matter, and afford a very nutritious kind of food, and flour prepared from them has been often mixed with wheat flour or with barley meal to make bread in famine years. They require a great deal of cooking, otherwise they are very indigestible. Many roots or tubers, as those of the potato, carrot, turnip, artichoke, &c., are used for food, partly on account of the large proportion of starch they contain, and partly because their cellulose or woody fibre, although indigestible, acts as a useful stimulant to the lining membrane of the digestive organs. These roots and the green parts of vegetables are especially valuable for the potash salts of organic acids (as the citric, contained in lemons and limes, the malic in apples and in rhubarb, the tartaric in grapes, &c.). When such vegetable substances are absent from the food, scurvy is always produced, unless substances containing the salts just mentioned are used. For this reason it is now the practice, when sufficient quantities of preserved vegetables cannot be had, to take supplies of lime juice on long voyages, to prevent the outbreak of scurvy, a disease which used to cause a terrible mortality, especially in our navy.

§ 32. **Alcoholic liquors.**—All these liquors contain other substances besides alcohol. They are naturally divided into distilled or ardent spirits, wines, and beers. Distilled spirits consist merely of alcohol and water, with flavouring materials, and differ from

one another only in the method of preparation and the substances from which they are prepared, and from which each gets its flavouring material. The amount of alcohol in these spirits is on an average about as much as in proof spirit, viz. 49 per cent. by weight, but it frequently exceeds that amount. The effects produced by drinking spirits habitually are indigestion caused by an alteration of the mucous membrane of the stomach, which prevents it performing its functions properly and consequently occasions a deficient nutrition of the blood, since if food is not properly digested it cannot be absorbed; and then an alteration in the structure of the liver, to which organ the blood from the coats of the stomach and intestines containing alcohol first goes—an alteration consisting in the overgrowth of the fibrous structures, which thus compress the liver substance proper and prevent it from performing its work in the right way. This is accompanied by an impediment to the flow of blood from the portal vein through the liver, the increase of fibrous substance obstructing its passage through the capillaries and pressing upon the branches of the portal vein, and so the blood from the walls of the stomach and intestines, being prevented from having a free passage through the liver, exerts pressure on the walls of the capillaries, and its serum exudes through them into the cavity of the peritoneum—the bag which is folded round the organs in the abdomen, and which forms their external coats. This serum, or 'water,' as it is commonly called, collects in the sac of the peritoneum, forming a kind of dropsy, distends the walls of the abdomen, pushes the organs contained in that cavity out of their places, presses

upon the diaphragm, so that respiration becomes difficult, and even the action of the heart is interfered with, and then has to be removed by tapping. The structure of the liver is so essentially altered, and the alteration is so well recognised as being produced by the drinking of spirits, that such a liver is called by physicians of different countries by the name of the spirit commonly drunk there. In England it is known as 'the gin-drinker's liver.' Besides this, the blood not being properly supplied with nutriment, and the oxidation of waste substances in it being interfered with, as was before stated, it does not properly nourish the tissues, and they degenerate one and all. The kidneys, the important excretory organs of waste substances containing nitrogen, also become diseased, and so kidney disease is far more prevalent amongst those who drink alcoholic liquors than amongst those who do not. It has been proved quite conclusively by Dr. Parkes and others, that men who drink spirits are capable of doing much less work than those who do not, and of doing much less work themselves at a time when spirits form part of their food than when they do not. Spirits are especially dangerous in hot countries, as they increase the tendency to liver disease; and they are hurtful in cold climates, because although they give a temporary fillip to the circulation, they do not, as has been before said, increase the animal heat, but rather the reverse; and the depression which follows their use continues for a far greater time than the temporary excitation originally produced. *All experience shows* that men who drink spirits are *much less able to* withstand extreme cold than those

who do not. It is often said that when spirituous liquors are diluted with water in the way in which they are commonly drunk, they do not contain a larger percentage of alcohol than wines or even strong ale; but spirits are nearly always drunk a considerable time after meals—often late at night, when the stomach is nearly empty, and they do not themselves, like wines and beers, contain a considerable proportion of other substances than alcohol, so that absorption goes on very rapidly through the coats of the stomach and intestines into the capillary blood-vessels, and this is the main reason why spirituous liquors do so much more harm than other alcoholic drinks. The flavouring materials of the spirits have likewise their own special deleterious effects. This is especially the case with fousel oil, which is contained in raw, unmatured whisky.

Wines and beers differ from distilled spirits in containing smaller percentages of alcohol and much larger quantities of other substances. The strong wines, as port and sherry, contain from 10 to 14 or 15 per cent. of alcohol, and, as sold in this country, part of the alcohol has been almost invariably added to them in the form of brandy. The drinking of strong wines and strong ales is not known to produce so marked an effect upon the liver as the drinking of spirits, but the oxidation of waste substances in the blood is impeded, and the nitrogenous substances instead of being converted into urea, which can be excreted by the kidneys, are left in the condition of uric acid, of which the kidneys can only excrete a small quantity. The kidneys become diseased, and uric acid is

deposited in various tissues of the body, resulting in the production of the disease known as gout. This effect is more certainly brought about if too much animal food be eaten at the same time. It is still worse if strong wines and ales be drunk at meal-times, for the alcohol precipitates pepsin, the ferment of the gastric juice, and so the food cannot be digested.

The lighter wines and weaker beers contain much smaller percentages of alcohol — table beer only containing from 2 to 4 per cent.—and a relatively much larger percentage of other substances. Wines are chiefly valued for their flavour, known as the 'bouquet,' as is shown by the extraordinary prices that are given for delicately flavoured kinds. The use of the lighter beers as a beverage is chiefly due to the bitter principle of the hop which they contain. When taken in strict moderation, these (both wines and beers) may stimulate the appetite and promote digestion, where this is required, but when taken in excess they produce intoxication, with all its evil results, direct and indirect.

Although alcohol is useful in many forms of disease, it is not necessary to life in health, and all who cannot be strictly moderate in the use of these liquors had much better abstain from them altogether. Dr. Parkes lays down as the limit of moderation an amount of alcoholic liquor in 24 hours containing not more than 1½ fluid ounces of pure alcohol; this is equal to 1½ pints of beer, containing 5 per cent. of alcohol, or half the quantity of French wine containing 10 per cent.

§ 33. **Tea, Coffee, and Cocoa.**—In almost all countries, and under all circumstances of life, the inha-

bitants have prepared decoctions from these plants or from others possessing similar properties. They resemble all vegetable decoctions in containing an astringent substance called tannin, and like many other decoctions contain aromatic oils. But their peculiarity consists in the presence of a substance called *theine* when prepared from tea, and *caffeine* when prepared from coffee, or of some substance of similar properties. This substance, which is a poison if taken pure, has the property of stimulating the nervous system and of retarding the waste of tissues, and so enabling the food to go further, as it were. These drinks are valuable both in hot and cold climates; cooling in the former, because they promote the action of the skin, and so increase the amount of evaporation from the surface; and warming in the latter, not only because they are drunk warm, but because they economise the food. As theine is soluble in boiling water, but much less soluble in water at a lower temperature, it is essential to use water which is actually boiling in the preparation of the decoction, and most of the essential principle is extracted by the boiling water at once, so that, when the decoction is allowed to stand with the tea leaves or coffee grounds in it for some time, it is strengthened chiefly by the addition of colouring matter and the astringent substance called tannin. This latter has a mischievous action on the digestive apparatus, hindering the secretion of gastric juice, and preventing the digestion of food, and so it is very unadvisable to drink strong tea and coffee during meals, and if these liquids are drunk at meal-times they should be *mixed with* large quantities of milk. These beverages

are often drunk too hot, in which case they injure the lining membrane of the stomach, and produce indigestion, with all its mischievous consequences. Coffee is much more exhilarating than tea, and more oppressive to the stomach. It is often mixed with ground chicory-root for the sake of economy.

Cocoa contains a substance very similar in properties and chemical composition to theine, but it contains also a considerable proportion of albuminous and fatty matters, and therefore forms a nutritious beverage, especially when prepared, as it usually is, with milk. It is also less liable to produce wakefulness, and so is better suited to many persons.

§ 34. **Proper Allowance of Food.**—The average amount of food consumed daily by an adult taking moderate exercise is found to contain the following weights of *dry* food substances :—

Nitrogenous substances .	4½ ozs.
Fats	3 "
Carbo-hydrates . . .	14¼ "
Salts	1 "
Total	22¾ "

This is equivalent to about 40 ozs. of moist solid food, and besides this from 50 to 80 ozs. of water are taken in the form of beverages. With violent exercise or severe bodily work the amounts are considerably increased under each head. With rest, on the other hand, they are diminished, and the amount of food which is required to keep a man alive contains on an average about 14 ozs. of dry solids. If an excess of

food be taken, especially with too little exercise, it is not digested, but undergoes decomposition in the intestines, with the formation of fœtid gases, and produces great disturbance of the digestive apparatus. But the system may become accustomed to digest and absorb more food than is necessary, and the result is the deposition of too large an amount of fat all over the body, and even in tissues which ought not to contain fat, producing the state known as obesity, or the development of gout, disorders of the kidneys, &c.

When too little food is taken, or too small an amount of any one of the classes of food substances is contained in the diet, a loss of weight takes place, because the tissues of the body are wasting faster than they can be replaced. This is soon accompanied by loss of strength, and often by great prostration, and ultimately causes death, which is much hastened if too little water be taken with the food. The fatty tissue all over the body loses weight first, and for a time takes the place in the blood of the food that is wanting. The parts which lose weight least are the bones, the eyes, and the nervous system.

§ 35. **Times for Meals, &c.**—In this climate the practice of taking a hearty meal soon after rising in the morning is a sound one. The system is exhausted by a long fast, and requires preparation for the day's work. In warmer climates it is the usual practice to postpone the first hearty meal until later in the morning, checking the call of hunger by a light refreshment, as a cup of chocolate, or *café-au-lait* and a roll. This practice is defensible on the ground that a smaller amount of food is necessary in warmer climates, and that two

good meals in the day are sufficient. The first hearty meal must not then be taken too soon, or the interval between it and the other would be too great, and it is quite a mistake to leave too long an interval between meals—over-eating and consequent indigestion being the invariable results. Suppose, then, that a hearty meal be taken soon after rising, it becomes necessary to decide when the chief meal of the day is to be taken, and this is a matter which is practically decided by habits of business or social considerations. If it be taken in the early afternoon, as is often the case, and a light tea at five o'clock, another meal is necessary during the evening. This, however, should neither be a too hearty one nor be postponed until just before bed-time, and it is very important that it should not contain indigestible substances—disturbed sleep being the result of the neglect of these precautions. When, on the other hand, the chief meal of the day is taken late in the afternoon or early in the evening, it is necessary to partake of some light refreshment in the middle of the day. If this be not done, the interval between breakfast and dinner is too long; but nevertheless, a heavy lunch in the middle of the day is a mistake, as being unnecessary before a late dinner. The practice of taking a cup of tea between lunch and dinner is, to say the least, unnecessary, and if it be indulged in, the longer the time left between it and dinner the better. The custom of taking a small quantity of coffee or of tea soon, but not too soon, after dinner is a good one, except where it produces wakefulness at night; and although no kind of meat should be taken after a late dinner, it is a good plan, especi-

ally for those who sit up very late, to eat a hard biscuit immediately before going to bed, as this tends in a very marked manner to counteract sleeplessness.

CHAPTER VI.

WATER SUPPLY.

§ 36. **Water.**—Water is required not merely for drinking, but for cooking, washing, &c.; and these may be called its household uses; it is also required for public purposes, for cleansing the streets, flushing the sewers, supplying fountains, public baths, &c. It is quite clear that there is no need for the water which is used for several of these purposes to be as good as that which is required for drinking; and so in some places it might be found to be advantageous to have a supply of pure water for drinking and cooking, and another of an inferior quality for other uses, and this is what was done in ancient Rome. Practically, however, it is more usual to have only one supply of water for all purposes, and so we have to assume that the water supplied to a community ought to be water that is fit to drink. The characters that such a water should present are these: it should be clear, colourless, aërated, fresh to the taste—that is, neither salt nor sweet—should have no suspended particles in it, and should deposit no sediment on standing. If it does not present all these characteristics it should at any rate be looked upon with suspicion. Water which is not aërated, as the

water obtained in very high places, or distilled water, or melted snow or ice, is not so readily absorbed by the coats of the stomach, and in some sense acts as a foreign body. Water which is too cold is liable to produce diarrhœa, and the same is the case with the water which contains suspended matters of any kind, whether mineral or organic, and so turbid waters ought always to be avoided. The presence of fine particles of mica suspended in the water actually causes dysentery in some parts of India.

§ 37. **Mineral Impurities.**—Water may, however, fulfil all these conditions and yet not be a good drinking-water, for it may contain substances in solution which may render it unfit to drink. The substances that water contains in solution, as a general rule, are, in the first place, mineral salts, and then organic matters, and the products of their decomposition, salts of ammonia, nitrates and nitrites, &c. Of the mineral salts carbonate of lime (calcium carbonate) is of most frequent occurrence, and is held in solution in the water by means of free carbonic acid, which most natural waters contain. The presence of this salt in moderate quantity in water certainly does not render it injurious. Then come other salts of calcium, as the sulphate, nitrate, and chloride. These are soluble in water itself without the aid of carbonic acid, and this is the case also with the sulphate and chloride of magnesium. All these salts have an injurious effect upon the water, and render it liable to produce diarrhœa or some other disturbance of the digestive apparatus in persons who drink it. The drinking of water containing magnesium salts is also believed to be the cause of

the swelling of the thyroid gland in the throat called goitre, so prevalent in some parts of Switzerland and of the Rhine country, in parts of France, &c. It is also occasionally found in England, and from its prevalence in one county goes by the name of the 'Derbyshire neck.' Common salt (sodium chloride) frequently occurs in small quantities in natural fresh waters, and may occur in much larger quantities in water derived from wells near the sea-coast or sunk in salt-bearing rocks. Except under these circumstances any but very small quantities of salt should be looked upon as a suspicious circumstance, indicating probable contamination of the water with animal refuse matters, as by percolation from a sewer or cesspool. Salts of ammonia are present in infinitesimal quantities in all natural waters, even in rain-water, but their presence in anything but these very small quantities (except in deep well waters) is owing to the presence of decomposing organic matters, and is to be regarded as an impurity. Nitrates, especially the nitrate of ammonia (or ammonium nitrate), are found in small quantities in all natural waters, and in considerable quantities in certain waters, but they are frequently formed in waters by the oxidation of nitrogenous organic substances. It has, therefore, been proposed to consider their amount as a test for the quantity of impurity that has at any time had access to the water —the 'previous sewage or animal contamination,' as it is called. The practical value of this test is, however, much lessened by the fact that many natural waters which have not been rendered impure contain *considerable* quantities of nitrates.

§ 38. **Organic Impurities.**—It is the presence of decomposing organic matters, whether in solution or in suspension in the water, that especially renders water unfit to drink. When such water is drunk, especially if the organic matters be of animal origin, as in the case of water polluted by sewage or by the drainage of a graveyard, the result is frequently the production of diarrhœa, or in hot climates of dysentery; and in certain instances—that is to say, when the poison of the disease has been introduced along with the polluting material—the production of cholera or typhoid fever; and in the case of water derived from marshes, which contains a large quantity of vegetable matter in suspension and solution, the production of intermittent fevers or ague. Dr. Snow first showed in 1849 that cholera poison might be distributed by means of drinking-water. Soon afterwards occurred the celebrated case of the Broad Street pump in Westminster, when it was shown that the families who had cholera in that neighbourhood derived their water from this particular pump, while those who did not use this water escaped; and since that time a considerable number of cases have been observed in which it has very clearly been shown that the cholera poison is frequently conveyed in drinking-water. A good example of this on the large scale is to be found in Mr. Simon's report on the cholera epidemics in London in 1848–9 and 1853–4, in which it was shown that the cholera prevailed especially where impure water was distributed. Thus, when the Lambeth Company took its water from the Thames near Hungerford Bridge the people who were supplied died at the rate of 12·5 per thousand.

When the source of supply was moved up to Thames Ditton the mortality was only 3·7 per thousand, while at the same time and in the same districts the mortality among the people who were supplied with water by the Southwark Water Company from the Thames at Battersea was at the rate of 13 per thousand. Cholera has even prevailed on one side of a street and not on the other which was supplied with water by a different company. Nay, more, it has appeared in houses supplied with polluted water, and not in those on the same side of the street supplied with pure water from another source. When Glasgow was supplied with impure water from the River Clyde, the number of deaths in cholera years varied from over 2,800 in 1832 to nearly 3,900 in 1854. After a supply of pure water had been obtained for the city from Loch Katrine, the number of cholera deaths in 1866, the next cholera year, was only 68.

The evidence as to the spread of enteric (typhoid) fever by the same means is, if anything, more complete, for many hundreds of epidemics of that disease have been clearly traced to the use of polluted drinking-water; the source of pollution having been generally also found, and impurities detected in the water by chemical analysis. This fever used to be exceedingly prevalent in Millbank Prison when it was supplied with water directly from the Thames, but has entirely disappeared, as shown by Dr. De Renzy, since a purer water has been obtained. With regard to the production of malarious fevers by drinking the water of marshes there is a great deal of contradictory evidence. On the whole, however, the evi-

dence is in favour of the belief that this is one of the ways in which these fevers may be propagated, and the inhabitants of marshy countries are accustomed to drink water in the form of tea or coffee, in order to avoid taking marsh diseases. The evidence with regard to diphtheria and ulcerated throat is not quite conclusive. Instances are on record in which they have been attributed to the drinking of foul water; but it is quite certain that they are far more frequently due to the breathing of foul air, although, as the poison or foul matter which produces them may be present in either, it is quite possible that, as has been stated, some cases may have a water origin. The eggs or embryos of several kinds of intestinal worms are also frequently contained in impure surface waters, as ponds, ditches, &c.; and in such cases even small leeches may be drunk with the water, and produce serious symptoms.

§ 39. **Hard and Soft Water.**—Water used for domestic purposes is called 'hard' or 'soft.' Hardness depends on the presence of mineral salts in solution in the water. The smaller the quantity of these, the softer is the water. There is no evidence that the drinking of moderately hard waters is disadvantageous to health, but hard waters are not so useful as soft ones for other domestic purposes. Tea is not made so well with them, and a large amount of soap is wasted. The value of soap for cleansing purposes depends upon the property that its solution in water has of producing a lather. *Soap consists of* combinations of certain fatty acids (*or acids prepared* from fats), with soda (hard soaps)

or potash (soft soaps). When mineral salts, as those of calcium, magnesium, and iron, are present in the water, insoluble compounds of these fatty acids with the oxides of calcium, magnesium, and iron are produced, and until this is done no lather is formed, so that the more of these mineral salts the water contains—that is to say, the harder it is—the more soap is wasted by its use.

§ 40. **Sources of Water.**—The occasional sources of water supply are, firstly, dew and rain. Dew has been collected at sea when the supply of fresh water has run short by exposing fleeces of wool to the air through the night, and wringing them out in the morning. Rain affords in country places a very pure and soft water—too soft, indeed, to be pleasant to drink. This supply should be much more utilised than it is, and it is advisable to resort to it whenever the usual water supply is suspected to be polluted, as during epidemics of cholera or typhoid fever. Rain-water in and near large towns is, on the contrary, very impure and quite unfit to drink, so that it cannot be regarded directly as a source of water supply. There are also melted snow, ice, and distilled waters. All these are very pure, containing scarcely any salts or gases. From their want of aëration they are not agreeable to drink, and when they are used, as in the case of distilled water (which is now largely used at sea), it is advisable to aërate them by letting the water fall from one cask into another through a number of small holes in the bottom of the upper one. The sources of water supply which are actually resorted to on the *large scale*, and which are all derived indirectly from

rain, are springs, wells, rivers, and lakes. When rain-water falls upon soil which is pervious to water a certain proportion of it sinks through the pores until it comes to an impervious stratum, as a layer of clay, which it cannot percolate. It then runs along on the top of this until the stratum in question appears on the surface of the ground, when the water issues as a spring. As it passes through the rocks it dissolves mineral salts, and containing (as rain-water does) a considerable proportion of carbonic acid gas, it dissolves more of these salts, and especially of calcium carbonate, than pure water can do of itself; and so spring waters, although varying much in composition according to the rocks through which they have passed, are, as a rule, hard waters. They may indeed contain so much calcium carbonate in solution that they become petrifying waters, or so large a proportion of certain other mineral salts as to be medicinal in their properties, in which cases it is quite clear that they are not fitted to supply drinking-water. Surface wells are made by digging down from the surface of the soil to below the level of the subsoil water, or 'ground-water' as it is sometimes called, which is found at a depth from the surface which varies with the character of the soil, the amount of rainfall, &c. These wells often afford a considerable quantity of water, but as the water from the soil all round them for some distance percolates into them, the water they contain is very frequently (especially when they are in towns or near to houses) rendered impure; as foul refuse matters—the leakage of drains, cesspools, &c.—find their way into it and contaminate it. This is not the

case with Artesian wells, which are made by digging an ordinary surface well first, lining it with brickwork set in cement, so that the subsoil water cannot percolate into it, and then boring from the bottom down through the rocks until a water-bearing stratum is reached, when the water rises up through the boring into the surface well, which acts as a reservoir, and from which it may even overflow. To explain better how this is we will take the example of the London basin. The chalk is for the most part a pervious water-bearing rock. It comes to the surface forming hills both north and south of London. Between these hills on each side of London it lies beneath the surface, and is covered over by an exceedingly impervious stratum called the London clay, above which in turn there is in many places a surface sand or gravel. When a well is made in the surface sand or gravel the water which collects in it is almost always very impure for the reasons mentioned above; but when a boring is made through the London clay into the chalk below we generally get at a supply of pure water which has not been contaminated. This water comes from the rain which has fallen upon the chalk hills north and south of London, and sinking into the porous chalk percolates, chiefly through fissures in it, into the mass of chalk lying underneath London, from which it cannot escape by reason of the impervious layer of London clay which lies over the chalk. This water in the chalk is under considerable pressure, and so when a hole is made through the London clay into the chalk the water rises readily through it.

The quality of water varies very much according

to the rocks from which it is derived. The water from granitic and volcanic rocks issues in small streams from the fissures. It is usually very pure, containing only a small amount of mineral salts, and scarcely any organic matter in solution. That from hard limestones, as the Mountain and Oolitic Limestones, and that from the Chalk, is generally almost entirely free from organic matter, but is very hard, containing a large quantity of calcium carbonate in solution. The water from some limestone rocks contains magnesian salts, which render it objectionable. Waters from hard sandstone rocks are frequently very pure, especially those from the older sandstones. The new red sandstone, on the other hand, contains in many parts large quantities of common salt, and the water obtained from it is frequently brackish. In many instances for this reason borings made into it have been failures, so far as the water supply is concerned. The supply from loose sandstone and gravels is very variable in quality, but is frequently very impure. So is, as a general rule, water derived from clays, which frequently contain a considerable quantity of organic matter and in most instances calcium sulphate. River water is generally softer than spring water, as a good deal of the calcium carbonate contained in solution in the latter gets deposited. It contains, however, much more organic matter both in suspension and in solution, and is frequently rendered impure by receiving foul water from the towns along the banks of the rivers, so that as a rule it is not an advisable source of water supply. The water of lakes, on the other hand, is usually very pure, especially

when the lakes are fed by small mountain streams, and affords a very advantageous source of water supply for the towns in the neighbourhood.

§ 41. **Quantity of Water required.**—The amount of water used varies very much in different communities, but experience shows that where the allowance is scanty disease of various kinds is encouraged by the want of attention to the cleanliness of persons and of things, the want of sufficient water to flush the sewers, &c. About ten gallons a head a day are required for the various domestic purposes including bathing, about as much more for flushing drains and sewers, making twenty gallons a head a day ; and the average amount required for trade purposes is generally put down at another ten gallons a head, making altogether as a rough kind of average thirty gallons a head a day. Many towns are supplied with much less than this amount, which, however, must not be considered a high estimate, as indeed it would not be sufficient where there are large public baths or manufacturing processes requiring much water, or even a great number of animals ; and in ancient Rome the supply was so plentiful that there can hardly have been less than 300 gallons per head per day.

§ 42. **Conveyance and Storage.**—The Roman plan for conveying water to the towns to be supplied was to tap springs in the hills around the towns, and at a sufficient height above them, and convey the water by means of watertight pipes or aqueducts (either above or below ground as occasion required, crossing valleys by means of large inverted siphons), into large reservoirs in which the sediment was allowed to deposit,

and from which the water was conveyed by means of pipes to various parts of the town. This is an extremely good plan, and the Romans adopted it for all their large towns. For Rome they had nine large aqueducts bringing pure water into the city, and Rome is still supplied by means of some of these aqueducts, which have been repaired from time to time.

Or the water may be collected from springs, &c., over a considerable area, and brought into a large reservoir called an impounding reservoir, and so an artificial lake formed from which the town may be supplied by iron pipes. This is the more usual plan at the present day. In either case the water is received in smaller reservoirs called 'service reservoirs' in the town, which are covered and sufficiently large to contain a few days' supply. They are placed whenever it is practicable on high ground, according to the Roman plan, so that the houses may be supplied from them by gravitation. When this cannot be done the water must be pumped from them into a tank at a high level, from which the various parts of the town can be supplied.

When rivers are used as a source of water supply, the water is either allowed to flow directly from them into large reservoirs in which the sediment is deposited, or it is pumped up into these reservoirs; from them it passes on to filtering beds, and after having been filtered it is distributed to the town either by gravitation or pumping.

§ 43. **Distribution.**—There are two ways in which water collected from one of the sources just described may be distributed to the houses in the town: the sys-

tem of *constant service*, in which the main pipes and the branches into the houses are always full of water, and the system of *intermittent service*, in which the water is only turned into the mains at intervals for a short time, say once in every twelve hours. Of these the system of constant service is by far preferable from every point of view. With the system of intermittent service it is necessary to have receptacles, water-butts, or cisterns to keep the water in, and these, unless frequently cleansed, are liable to get foul (even when covered over so as to prevent the entrance of dust) from the sediment which collects at the bottom of them. With the intermittent system of service the foul air and foul water from the soil and from defective drains is liable to get into the water pipes through leaky joints during the intervals between the times when they are charged with water, and they contaminate the water when the pipes are next filled. With this system also there is always an immense amount of waste, as the ball-taps which should turn off the water when the cisterns are full are frequently out of order, and the water continues to flow and runs to waste through the waste or overflow pipes of the cisterns. Another danger arises when these waste or overflow pipes communicate, as they frequently do, with the drain or with some part of the sewerage arrangements. There is then a danger of foul air rising up them and contaminating the water in the cisterns. This foul air may contain suspended in it the poison of typhoid fever, which gets absorbed in the water, and produces that disease among the persons who drink it. These waste or *overflow* pipes ought always to end in the open air in

one of the ways that will be described in another chapter.

With the constant system of water supply the convenience is much greater, and the waste of water much less. The drinking-water need not be stored in cisterns, but can be drawn directly from a tap on the main, and the pipes are always charged with water in case of fire. The pipes, too, last much longer, as they are much less liable to rust than pipes that are sometimes filled with water and sometimes with air. When, however, in a town supplied with water on the constant system it becomes necessary for some reason or another—as during the cleansing of reservoirs—to resort for a time to the intermittent system of supply, most of the above dangers arise. Where the water supply is intermittent, and it is necessary to have a cistern to store the drinking-water, this cistern should not be used for any other purpose, and there should be separate cisterns for the supply of water-closets, &c. The main water pipes are made of cast-iron, and the service pipes for the houses usually of lead. Wrought-iron pipes are, however, preferable in many ways for this purpose. The cisterns are made of lead, slate, stone, iron, or galvanised iron (which is iron coated with zinc). An objection to leaden cisterns and leaden pipes is found in the fact that certain waters (especially soft waters) attack and dissolve lead, and many cases of lead poisoning from this source are on record. The danger, however, is not so great as might be anticipated, because, in the first place, most waters supplied to towns have very little action on lead; and, in the second place, the lead soon becomes

coated with an insoluble mixture of oxide and carbonate which prevents further action. Slate cisterns are liable to become leaky after a time, especially in large towns—probably from the continual vibration caused by the traffic—and the leaky joints are then generally smeared over with red lead in order to make them water-tight. Stone cisterns answer very well in the basement of houses, but they are too heavy to be used anywhere else. Iron rusts too fast, so that the best material for cisterns—the one of which they are now usually made—is galvanised iron. Very good cisterns are now also made of glazed stoneware.

§ 44. **Purification of Water.**—The water supplied to a town ought not to require purification. As Mr. Simon says: 'It ought to be made an absolute condition for a public water supply that it should be uncontaminable by drainage.' Where, however, the source of supply is a river, the water almost always requires to be purified on the large scale before being distributed, and this is done by filtering it. The filter beds through which it is passed consist of washed river sand and gravel. The water is poured on to the surface of the sand, and percolates through it and the gravel in fine streams into pipes below, from which it is conveyed to a pure water reservoir. By means of this process, in the first place, the suspended particles which do not subside in the settling tanks are mechanically arrested, and a film is formed on the surface of the sand through which even the finest suspended matters, such as microscopic organisms, cannot pass, and in the second place the organic matter in solution is oxidised by the agency of organisms in the interstices of the

filter, the result being the formation of nitrates and carbonates in the water. The action of a filter is therefore microscopical, biological, and chemical. Very hard water requires also to be softened on the large scale by means of Clark's process. In these waters the calcium carbonate is, as has been already said, held in solution by carbonic acid. Clark's process consists in adding milk of lime to the water. The lime thus added combines with the free carbonic acid gas, producing calcium carbonate, and so rendering it impossible that the quantity of this salt contained already in the water should be held in solution. It therefore falls to the bottom as a precipitate, together with the carbonate containing the lime added. The calcium carbonate or chalk as it falls to the bottom carries down with it any suspended matters that the water may contain, and leaves it very clear and pure. Filtration through sand and gravel to be successful in the purification of water requires to be downward and intermittent. Upward filtration will not do, for the water then, instead of falling through the filtering material in a multitude of small streams, rises through it against gravity in one mass, and displaces the air contained in the porous material; consequently little or no oxidising action takes place. Filtration must be intermittent as well as downward, so that the filtering material may have time to get filled with air again during the periods of intermission. It is usual to have several filtering beds and to use only one at a time, so as to leave each a sufficient *period for rest* and aëration.

On a small scale water may be purified by boiling

or by filtration. Water is generally made softer by boiling, for when water containing calcium carbonate dissolved in carbonic acid is boiled, the latter is driven off, and the calcium carbonate deposited. It is this substance which forms the greater part of the crust inside boilers. There is no doubt also that impure water is rendered more fit to drink by boiling, although it requires to be aërated in some way before being agreeable to drink. In countries where very impure water is drunk, some kind of vegetable infusion, as that of tea or coffee, is made, as before mentioned.

In filtration on the small scale, the chief material in use is animal charcoal, which when well prepared is a good filtering material, and purifies the water to a very considerable extent, but when of inferior quality becomes the breeding place of myriads of small worms. Silicated carbon and spongy iron, neither of which is liable to this objection, are both excellent filtering materials. In some household filters the water is first made to pass through a piece of sponge, with the view of separating the grosser suspended matters. This is not a good plan, as the sponge soon becomes dirty and requires to be renewed; it is also liable to become infested with microscopic animals and plants. Filters should be allowed to run dry from time to time, in order that the filtering material may be aërated. None of the above-named filters can, however, be relied upon to free the water from organisms. For this purpose the Pasteur-Chamberland filter, in which the water is made to pass through fine unglazed porcelain, and the Berkfeld filter, in which it passes through a tube made of a finely porous siliceous rock, have been devised.

CHAPTER VII.

REMOVAL OF REFUSE MATTERS.—TOWNS.

§ 45. **Necessity of Removing Refuse.**—Just as it is necessary for the health of the individual that the excretions of the lungs, kidneys, skin, and intestinal canal should be separated from his body as speedily as possible, so it is essential to the health of the community that waste substances should be continuously removed as fast as they are produced. Among such waste substances are the solid and fluid excreta of human beings, the water that has been used for washing, cooking, &c., waste animal and vegetable matters of various kinds, and lastly 'dust,' which should not, but frequently does, contain kitchen refuse. When these waste matters are kept in and about houses they decompose and give off foul effluvia into the air, and when kept in heaps or in pits on the premises foul matters from them percolate into the soil, and may pass underneath the houses, rendering the ground there foul, or into the wells, rendering the water unfit to drink; so that the air, the water, and the soil are rendered impure, and the health of the inhabitants is thereby endangered. In all towns where such refuse matters are stored up, instead of being got rid of as quickly as possible, there is a high general death-rate, and also a high death-rate from enteric (or typhoid) fever, and from cholera when it is epidemic. On the other hand, a more efficient and speedy removal of these refuse matters from towns has always been

followed by a diminution in the general death-rate, and an especially marked lessening of the mortality from enteric fever and cholera, so that the removal of refuse substances is of the first importance to the health of the community. Since, however, almost all of these waste substances, and especially the solid and fluid excreta, contain that which is valuable as manure for plants, it has been almost universally the practice to collect these substances, or part of them, with the view of turning them to account; and the various methods by which this is done go by the name of the 'Conservancy Systems.' But as all the foul water could not be collected and removed in a similar way, it had to be turned into the drains, the natural function of which is not to remove foul water, but to carry off excess of rain-water to the rivers, and so to prevent the soil from becoming damp; but just as it was in the case of the Cloaca Maxima at Rome, which was first constructed to drain the ground, but soon became used for the removal of foul matters from the houses, so in many other instances it was observed that the drains could be used not only for the removal of foul water, but for the removal with it of solid excretal matters by gravitation cheaply and quickly. So arose the 'Water Carriage System.' We have then these two plans: the Conservancy Systems, by which the solid and part of the liquid refuse matters are kept in and about habitations for a considerable length of time, with the view of utilising them as manure; and the Water Carriage System, by which they are removed with the foul water, not necessarily or properly by *means of* the drains, but by means of special pipes,

called sewers, continuously, as fast as they are produced; the question of utilisation being left for after consideration.

§ 46. **The Conservancy Plans.**—The solid and part of the liquid excretal matters were formerly, and in many places at the present time still are, either collected in pits dug in the soil, called 'cesspools,' or mixed up with a heap of ashes and refuse of various kinds, called 'the midden heap.' In very porous soils the cesspools were covered permanently, and never required emptying, the soil being so porous that, practically speaking, all the excretal matters percolated away into the neighbouring wells. In other instances the cesspools required emptying at greater or less intervals, but in all cases they were reservoirs, or rather manufactories, of foul gases, connected by the drains with the interior of the houses, and frequently situated immediately under them. The midden heaps in like manner were foul collections of decomposing refuse close to the houses. The first improvement upon these plans was the making of the cesspool watertight, by lining it with bricks set in cement and coating it with cement on the inside; or the construction of an impervious pit or receptacle to contain the midden heap, the cesspool having frequently an overflow-pipe from its upper part, and the midden heap a drain from its lower part, to carry off the excess of foul water into the nearest drain or watercourse. Such large impervious cesspools are still in use in many places, and *notably in many* continental towns, where they are *either immediately* underneath the houses or under

the courtyard in the middle of the house. They constitute, however, but a slight improvement upon the simple pit dug in the soil, and are in every way objectionable from the point of view of the public health. The next improvement, and a much greater one, consisted in reducing the size of the receptacle to the smallest possible dimensions, and so attempting to secure two important objects: the impossibility of collecting large quantities of foul matters in and about the houses; and secondly, their much more frequent removal. The cesspool thus became reduced to a mere tub or pail under the seat of the closet; the dimensions of the midden heap were limited to the space between the seat of the closet and the ground, the floor and sides of which were lined with an impervious material, and the front made movable so that the contents could be dug out with a spade when necessary; or a box was placed under the seat which could easily be removed.

By this plan the excretal matters are collected, either without any admixture with other substances, or mixed with ashes and other refuse matters, forming a more or less solid mass. In either case, when the receptacle is a movable one, the full one is taken out and carried away, being replaced by a clean empty one. As it was found that the solid excretal matters could be kept much longer without decomposing if separated from the liquid excreta, perforated partitions, called 'separators,' were placed in the cesspools, and even in large tubs, by means of which the solid matters were retained and the fluid either collected in another compartment or allowed to run away into the

drain, as in Cheshire's tank. In the Goux system the tub or pail is lined with a thick layer of absorbent materials, and the solid matters are collected in the centre, while the fluids are absorbed by the surrounding materials.

In another plan, ashes are placed between the two receptacles with the same object. A still further improvement consisted in the provision of an arrangement for sprinkling the refuse matters with some absorbent material as soon as they are deposited—ashes and dried earth being the substances most frequently used. One or other of these materials is placed in a box, or 'hopper' as it is called, from which a certain quantity can be discharged upon the refuse matters, either by pulling a handle or by an automatic apparatus connected with the seat or door of the closet. Where such a system is used, the advantages of ashes for the purpose mentioned are obvious, as every part of the waste matters of a community have to be got rid of somehow; but the claims of dried earth for this purpose must be considered more particularly. Earth of most kinds, except chalk and sand, if dried and thrown over excretal matters at the time they are deposited will, if in sufficient quantity, entirely deodorise them and dry them up, absorbing as it does a considerable quantity of water. It is found, too, that this earth may be dried and used for the purpose over and over again, and that no nuisance whatever is produced if the process be properly managed. The immense expense, however, that would be incurred in collecting so large a quantity of earth, amounting to 1½ lbs. a day for each person (even if all the slop-water were allowed to go into the drains), and of

drying and distributing it to the houses and removing it mixed with excretal matters, as would have to be done in the case of a town, would be a serious difficulty, unless the mixture proved to be a valuable manure. Besides this, the many attendant risks, such as the possibility of the supply of earth failing even for a single day, or of its being insufficiently dry, in which case it would be inoperative, or of servants throwing pails of slops into the closet, or the closet apparatus being out of order (in any of which cases the system would altogether or partially fail, and a serious nuisance be created), make it quite impracticable for any large community. So far from the 'compost'—as the mixture of excretal matters and earth is called—being a valuable manure, it is shown by the analyses published by the Sewage Committee of the British Association to be, even after passing five or six times through the closets, nothing more than a rich garden mould, quite incapable of repaying the cost of carriage to any distance. It has been found, however, to answer well in small communities, as country villages; and in some public institutions, as boys' schools, asylums, prisons, &c.; or for temporary assemblages of people, as at fairs, racecourses, camps, &c.; provided that in all cases a responsible person be told off whose duty it is to see that everything in connection with the earth-closets is always in thorough working order. Without this provision, a nuisance is sure to be created.

§ 47. **Defects of Conservancy Systems.**—With regard to all these Conservancy Systems, it may be said that they are based upon a wrong principle.

In all of them the refuse matters are supposed to be kept in and about the house so long as they do not become a nuisance—that is to say, they are not got rid of continuously, nor even as fast as possible; in fact riddance, the most important thing as far as the public health is concerned, is put in the second place, while collection and utilisation, matters after all of secondary importance, are advanced to the first. As cartage is a very expensive method of removal, the less often removal is necessary the less expensive will the system adopted be to the inhabitants; and thus there is with all Conservancy Systems a tendency to keep the refuse matters on the premises as long as possible. They therefore become in a large number of instances an intolerable nuisance. None of these plans afford a manure which will bear the cost of carriage to any considerable distance, unless under quite exceptional conditions; and none of them have been made to pay the cost of their working, with the single exception of the Pail System, in which refuse matters are collected without admixture with any other materials at all, so that their value as manure is not lessened by the mixture of extraneous substances like ashes or earth. This system (which is the plan that has been practised in China for thousands of years, where all waste substances are scrupulously collected) is, however, not one that is suited to our habits; and, moreover, where it has been introduced, collection daily, or three times a week, requires to be resorted to, to prevent its becoming an intolerable nuisance, and thus the attendant expense is considerable. And after all, none of these systems deal with more than a small

part of the refuse matters of a household. All the foul water has still to be got rid of, and this enormously exceeds the weight of the substances collected by these systems. Thus the Indian Army Sanitary Commissioners tell us that 'for every lb. of human excreta removed under the Dry Earth System there are in every well-regulated establishment about 190 lbs. of fluid refuse, which must be otherwise disposed of;' and they point out that 'it is insufficient to remove only one class or cause of impurities and to leave the others; and no sanitary proceeding which does not deal effectually with all of them can be considered as sufficient for health.' There is still the foul water to be removed and purified, and the separation of the excretal matters from it does not make this process any easier. Indeed, on account of the smaller quantity of water used in towns supplied with dry closets, the sewage, although deprived of the solid excretal matters, contains, as has been shown by the Rivers Pollution Commissioners, almost as great a percentage of polluting ingredients as that of towns supplied with water-closets, where all the solid excretal matters are removed in the sewage itself. The sewage of towns supplied with middens is, on account of its staleness (being largely supplied from the drainage of the middens), much fouler. Even where one of the Dry Systems is adopted, pipes, called 'sewers,' for the removal of the foul water, are necessary; and so the 'Water Carriage System,' as it is called, does not differ from the 'Dry Carriage System' in making sewers a necessity (for they are a necessity *in any* case); but the difference is, that whereas with

a Dry Carriage System the foul water only is conveyed away by the sewers, in the Water Carriage System solid excretal refuse as well is washed into the sewers, and carried away in the foul water by gravitation, so that the expensive method of removal by cartage is got rid of, and the refuse matters are removed continuously as they are produced.

§ 48. **Sewers.**—Sewers being pipes for the removal of foul water require to be impervious to water, so that the foul liquid may not percolate through them into the soil. Drains which are pervious to water, so that the excess of water contained in the soil may get into them and flow away, are for this reason not suitable for sewers, and a separate set of pipes ought to be laid down for sewers wherever it is practicable. Large sewers are built of bricks set in cement, and have generally an oval section, with the small end downwards, as with this shape there is less resistance to the flow of the liquid. In exceptional instances they are made of large iron pipes. The sewers for small streets and for houses are now made of glazed stoneware pipes, called 'Sanitary Pipes,' with watertight joints. The main sewers are laid under the streets sufficiently low to drain the basements of the houses. They are gradually inclined from the higher levels in the town towards the lower levels, joining one another either with curves or at an acute angle, so that the flow of one current shall not impede that of another, and they gradually become larger and larger, until they end in one or more outfall sewers. These outfall sewers frequently discharge into the river on which the town stands; in which case not only is the sewage wasted,

but the river is polluted, so that its water is rendered unfit for the people in the towns lower down to drink, and foul deposits are formed in its course, which decompose, and give off poisonous gases which kill the fish. At seaside places the outfall sewers often end in the sea between high and low water mark. This results in the loss of the sewage, and the foul matters are moreover frequently driven back upon the beach by the tide. Lastly, the outfall sewers are often made to end in tanks, where the sewage may be purified in one of the ways which will be mentioned further on.

It is especially important that the sewage should be allowed to escape freely from the outfall. If any impediment is offered to it, as is the case when the outfall sewer opens into a river below the level of the water, or when the sea rises up into the outfall sewer, or by closing the flap at the mouth of the outfall causes an accumulation of sewage in the latter, or when a tank gets over-filled, so that the mouth of the outfall sewer is blocked up by the liquid in the tank—in all these instances foul air is liable to accumulate in the sewers, and to find its way from them into the houses; and where this has been the case, the death-rate from enteric fever has even been increased after the construction of sewers. A still more important cause of foul air in sewers is the accumulation of foul deposits in them, due to a want of sufficient incline or of sufficient flushing with water. Wherever a deposit of foul matters occurs, foul gases are evolved. For such reasons it is necessary that sewers should be freely ventilated. If sewers are well constructed and kept clean, foul gases are not formed in any con-

siderable quantity, and no nuisance is caused by the ventilators. If, on the other hand, sewers are badly constructed, or not kept clean, it is much better that the foul gases formed should escape by the ventilators into the open air than find their way through the house pipes into the houses. The ventilators of street sewers should be at frequent intervals, and should lead direct from the crown or upper part of the sewer to the level of the street, where they should be provided with open gratings. Below these gratings there should, however, be a small receptacle to catch gravel, mud, &c., that are swept through them off the street; and the sides of this receptacle should open into the ventilating shaft, which may also be conveniently utilised as a man-hole, by which the sewer may be inspected when necessary. If there are plenty of these ventilators no nuisance is produced by them as a general rule, because air is almost continually coming in at some of them and going out at others, and so the foul air is diluted with pure air as fast as it is formed; and when a ventilator does become a nuisance, it indicates that something is wrong with that part of the sewer. It has been proposed to ventilate sewers by means of pipes running up houses and ending above the roofs. This is generally quite unnecessary, and the ventilation by means of such pipes is much less efficient. The exception occurs at the head of a system of sewers, where it is frequently advisable not to have an open ventilator or ventilators at the level of the ground, but pipes leading up above the houses to carry off the foul air which tends to collect in the sewers in such a locality. Sewers have also been

connected with the flues of furnaces, with the view of extracting the foul air from them. It was, however, found that the action was either too violent or too irregular, and the system was finally abandoned when from an escape of coal gas into the sewers in Battersea the connection with the flue of a furnace resulted in an explosion, which blew the works down. The gully-holes at the sides of the road, if not properly constructed, or securely trapped, in a manner that will be described hereafter, or if the pits below them which are meant to catch gravel, &c., and prevent its getting into the sewers, are allowed to become filled with foul matters, may, however, cause a considerable nuisance. As the main sewers are usually laid under the streets, and the sinks, closets, &c., are at the backs of the houses, the house-drains (as house-sewers are now always called) have most frequently to be laid underneath the houses; and so it is all the more important that they should be well laid with a sufficient fall—such as 1 in 48—and that they should be made perfectly watertight, so that no foul matters may escape through leaky joints into the soil underneath the houses. They should be made of glazed stoneware pipes, or of heavy iron pipes coated with Angus Smith's preparation, as brick drains, or drains made of pervious pipes, under houses, become saturated with foul matters, and allow foul water to percolate into the soil. Moreover, rats find their way through them, frequently displacing the bricks or pipes, and so not only causing irregularities which favour accumulations of foul matters, but, as they work their way into the houses, forming channels

through which foul air from the badly-constructed drains is drawn up into the houses.

§ 49. **Disposal of Sewage.**—The next subject that has to be considered is what is to be done with the sewage or foul water, which we have seen must be got rid of somehow from all towns whether water-closets are used or not. This foul water contains substances dissolved in it and substances suspended in it. Of these the dissolved substances are far more valuable than the suspended matters. Two considerations arise: the one is how to get rid of the sewage without causing a nuisance, and the other how best to utilise it. In some places, the suspended matters are merely strained off from the sewage or allowed to subside, and the comparatively clear liquid turned into the nearest water-course. This liquid, however, contains foul organic matters in solution, and to a certain extent in suspension also. These soon putrefy and may render the stream very foul; they certainly make it unfit to drink. The matters that are strained off are almost useless as manure, and so the sewage is wasted. Many attempts have been made, by means of chemical agents, such as lime, alum, clay, phosphate of alumina, phosphate of lime with salts of magnesia, &c. &c., to separate the valuable constituents of sewage. None of these attempts have succeeded, as the most valuable constituents are the salts of ammonia, which cannot be separated by any such method from solution in large quantities of water. By means of such processes the suspended matters and part of the dissolved matters may be removed and the water left quite clear, but none of them separate out sufficient manurial ingredients to

make the precipitate valuable as a manure, nor do they leave the water in such a condition that it can be turned into a water-course which is to be afterwards used for drinking purposes. In one of them indeed (General Scott's process) the idea of preparing a valuable manure out of the sludge or precipitate is abandoned, lime and sometimes clay being mixed with the sewage, and the resulting precipitate collected, dried and burned, in order to make cement; while by another process bricks are made of the sludge. Since then by none of these means is the foul water so purified as to be capable of admission into a stream, while at the same time it is not utilised as manure, some other means for purifying, and if possible for utilising it must be adopted. It was shown by Dr. Frankland's experiments that foul water, when passed through a filter of soil, could be purified if passed downwards and intermittently. It was also shown that this purification depended upon an oxidation of the organic matters contained in the water by the oxygen of the air contained in the pores of the filter, as was explained in the Chapter on Water, and so the process of intermittent downward filtration through the soil was devised. By this plan, however, the sewage was not utilised, or only partially so, and its purification and utilisation can only be satisfactorily effected together by extending the filtering area, and growing crops upon it, so making a sewage farm. It is important to insist that a sewage farm shall be a filter of large area, that the foul water shall pass through the soil into the drains below and not merely flow over the soil from one ditch to another. When it passes through the soil it

is purified in winter, when there is little or no plant-growth, just as well as it is in summer. When, on the other hand, it is allowed to flow over the surface of undrained land, it is only purified in summer by means of the growing crops, and in winter it is not purified at all. In such a case the water flowing off one irrigated field has been known to be rendered more impure by passing across another one. All kinds of crops can be grown with sewage as a manure (although the judicious addition of certain other manures for particular crops may ensure a larger yield), but the staple sewage crop is no doubt the Italian rye grass, which will absorb an immense quantity of water, and will grow so fast that nine or ten crops may be obtained in a year. It should be cut and carried, and not grazed, and forms an excellent food for cattle, so that the sewage manure is ultimately turned into beef and milk. Besides the Italian rye grass, all kinds of vegetables, both for cattle and for the table, may be grown, and grown on land that was absolutely infertile before, as sea sand, for example; and not only so, but fruits and several kinds of cereals have been successfully cultivated by its means. Before turning sewage on to the land it would, however, be well to employ some kind of precipitation process by means of which the offensive suspended matters might be got rid of; and to provide for times when so large a quantity of water is not required by the plants, there should be on every irrigation farm a piece of land to be used as a filter for the purpose of purifying the sewage when necessary. With regard to the utilisation of the manure, the sewage of from thirty-five to forty persons

is usually considered to be sufficient for an acre of land on the average, although much more than that may be purified and advantageously used per acre, the amounts varying with different kinds of soil, depth of drainage, &c. Where the sewage can be delivered on to the land by gravitation the extra produce of the farm may cover the annual cost and the interest on the original outlay, or may even yield a margin of profit, but where the sewage has to be pumped on to the land, the town will generally be put to some charge. A properly conducted sewage farm is not a nuisance to the neighbourhood, and no injury to health has been found to be due to the proximity of one of them. The idea was started some years ago that parasitic diseases in cattle and therefore among men would be rendered much more prevalent by the employment of sewage on the land. There is not, however, the slightest evidence that such has been the case, while there is very strong evidence to the contrary. The increase in the power of production of meat, of green vegetables, and especially of milk, is also an extremely important matter, as is the consideration that the more we utilise our refuse matters the the more we are rendered independent of manures imported from other countries.

On the whole then, we may safely say that the only method at present known by which sewage can be purified and its valuable ingredients used as manure, is that of irrigation on cultivated land, so that wherever this plan can be adopted it should be, even where the town has to pay for successfully getting rid of its sewage.

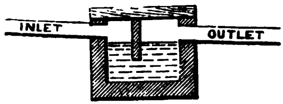
CHAPTER VIII.

REMOVAL OF REFUSE MATTERS (*continued*).—HOUSES.

§ 50. **House-Drains.**—The pipes for house-drains should not, as a rule, be larger than six inches in diameter, with four-inch branches. At the connection between the house-drain and the main sewer there is usually placed a small iron flap, swinging on hinges, so that it can be opened by the current of water flowing from the house-drain, but shuts again by its own weight so as to prevent rats, and, to a certain extent, air from the main sewer getting up into the house-drain. A water-trap of one kind or other should also be placed on the house-drain before its connection with the sewer or cesspool. A water-trap, whatever its shape, is essentially a bend in a pipe that will hold water to a sufficient depth to prevent air passing along the pipe, in order to prevent the foul air of the sewer or cesspool into which it discharges from passing up into the house-drain. The water-trap should not be too large, or foul matters will accumulate in it, and will decompose and fill the house-drain with foul air; it should, in fact, be so small that the water flowing from the drain will be sufficient to flush it out and to prevent foul matters lodging in it. It is essential to have the water-trap on the house-drain, as the air of the sewer or cesspool, besides being very foul, may contain the poisons of certain specific diseases, and it is very important to keep such poisons out of the house-drains. The oldest form of

water-trap is the Dipstone trap. It consists of a small pit, lined with bricks set in cement, covered with a stone slab, which is level with the top of the drain, the pit itself being some inches deeper than the bottom of the drain. This

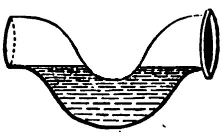
FIG. 10.



Dipstone Trap.

pit is generally made much too large, so it becomes practically speaking a cesspool; it need not be wider than the width of the drain across from side to side. Across it and reaching from the roof of the pit to two or three inches below the level at which the water stands in it (which is of course the level of the bottom of the drain pipe which leaves it) there is placed a slab of stone or slate, from which the trap takes its name. It will be seen that this slab prevents direct communication between the air on the side of it which is nearest to the main with the air on the other side which is in the house drain. There is much less chance of this trap getting blocked up with an accumulation of solid matter if it is rounded off inside so that there are no corners for things to lodge in, and the end at which the sewage enters should be made steep, while the other is sloped very gradually upwards towards the exit pipe. It is a good plan, too, to slope the Dipstone a little in the direction of flow of the sewage, and not to place it quite vertically. It

FIG. 11.



Stoneware Siphon Trap.

is, however, since the adoption of pipe drains, simpler

and cheaper to use a siphon trap, which is merely a pipe bent somewhat like the letter 'U,' and which therefore will always hold a certain quantity of water. These siphon traps sometimes get blocked up. The sand that is used for scouring, and small particles of earth, gravel, &c., from the yards settle down in them and are not flushed out by the water; hence it is best to have the limb nearest the house nearly vertical and the other limb sloped, whereby there is less chance of accumulation in the bottom of them.

It is therefore necessary to make a contrivance by which the siphon can be got at and flushed out from time to time by means of buckets of water or hose. This is done either by means of a man-hole, for access to the siphon, or by a vertical pipe taken up to the level of the paving, on the house side of the siphon. Instead of covering this pipe with a stone slab, an open iron grating should be placed over it, for a purpose which will be explained directly.

If it is important to ventilate the street sewers, it is still more so to provide free communication between the house-drain and the external air; this is best done by connecting a four-inch lead pipe, which may be the soil-pipe (pp. 121-2), with the drain at its highest point—that is to say, the furthest point from the main sewer—carrying it up outside the house, and making it end higher than the ridge of the roof, like a small chimney, with a perforated cap on the top of it to prevent birds building nests in it; no cowl is *necessary;* an inlet opening should be made at the *other end of the house-drain,* between the house and *the water-trap, through* which a current of air can

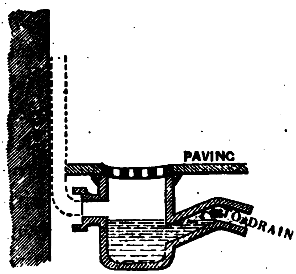
enter the house-drain. This opening may be provided in the way already mentioned, and serves the double purpose of a means of access to the siphon and of an inlet for air to the house-drain. (See Fig. 16.)

It is a good plan in cases where there is a long length of unventilated sewer, or, as in country places, a cesspool, on the other side of the trap, to connect a four-inch pipe with the sewer just beyond the trap, and carry a four-inch lead pipe from this up above the house, so as to prevent the accumulation of foul sewer air on the other side of the trap.

Rain-water pipes are usually either connected directly with the house-drain, so that there is a free passage of air between them, or indirectly by means of siphon traps. They should not be connected with the drains at all, but should end in the open air over the yard, unless they discharge into separate drains connected with a rain-water tank, the overflow drain from which should not be connected with the house-drain. Where they are connected with the drain and end above near windows, foul air gets blown from them into the house, and this is a frequent cause of sore throat, diphtheria, &c. Where they are made to end in siphon traps connected with the drain, there is the additional disadvantage that these are liable to get blocked up with leaves, &c., washed from the roof; and although wire gratings should be placed at the top to prevent this, these may get moved; and moreover they have the disadvantage that they sometimes get blocked up themselves, and prevent the water getting into the rain-water pipe, in which case it overflows the *gutter an l* runs down either outside or inside the house.

For all these reasons it is clearly necessary that the rain-water pipes should end over the yard, when there is no necessity for placing wire cages at the top of them, as it is better to allow the leaves to be washed down them on to the yard. In the yard paving there must be an opening leading to the drain; and this should be provided with a water-trap, to prevent air from the drain getting out into the yard. A stone ware siphon gully, with a galvanised iron grating, is probably the best form for this purpose; and such traps are made with a pit, which collects gravel, sand, &c., so that they are not washed into the drain. Where it is desirable to carry the rain-water pipe underneath the paving of the yard, it may be taken into an opening in the side of the gully above the water in it. Other traps used for yards are the LIP TRAP, which consists of a small iron box, with a grating at the top and a partition, or 'lip,' which dips below the surface of the water, and, like the stone in the Dipstone trap, allows the water to flow away underneath it, while it prevents foul air finding an exit; and the BELL TRAP, which differs from those that have been described in that when the perforated plate at the top is removed (as it almost invariably is when the yard is swept down), an open communication with the drain is established. In this trap

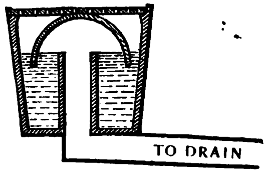
FIG. 12.



Stoneware Siphon Gully, with side inlet.

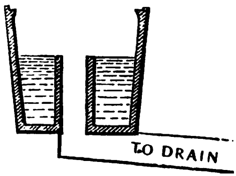
there is a bell-shaped piece of iron fastened on to the under side of the perforated plate. The edge of this bell when in its place dips a short distance below the surface of water contained in a circular trough of iron, through the middle of which there rises a small pipe connected with the drain, which small pipe therefore ends wide open inside the bell. It will thus be seen that when the bell is in position water can flow through the perforated plate and under the edges of the bell down the pipe into the drain; but the foul air rising up the pipe would be stopped from escaping by the bell unless it had sufficient pressure to force its way through the water into which the edge of the bell dips, or unless (a thing which frequently happens in dry weather) the water evaporates so that the edge of the bell is no longer covered. The great disadvantage, then, of the bell trap is that when the bell is taken off or broken the trap is done away with, and the use of such traps, which is so common, not merely outside houses, but even inside, especially in the basement floor, is perfectly indefensible. It is very common to have a trap opening in the floor of the kitchen or scullery connected

FIG. 13.



Bell Trap with cover on.

FIG. 14.

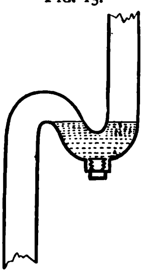


Bell Trap with cover removed.

with the drain, so that the scullery can be flushed down with water, or the water escape in case of the overflow of a cistern or bursting of a pipe. The trap used most frequently for this purpose is the 'bell' trap, the water of which soon evaporates in the heated atmosphere of the basement, so that the drain is ventilated into the house, and serious results may ensue. A siphon gully is much better, but any trap opening in the floor of the basement connected with the drain is highly objectionable, and where it is necessary to provide for the flow of water from the basement, this should be done by a separate pipe leading out into the yard and ending there over the surface, if this is lower than the basement, or else into a gully underneath an open grating, as with rain-water pipes.

§ 51. **Sinks.**—The waste pipes from sinks are commonly trapped in the same way and then allowed to enter the drain. This plan is objectionable in all cases, but is especially so when the trap is merely a bell trap placed over the waste pipe of the sink, as this is frequently taken off and not replaced, and so air from the drain enters the house. These waste pipes should have a siphon trap immediately under the sink to prevent the air entering the house through the sink, and should then be carried through the wall, and made to end over an open grating or under it, but above the water in the trap below. Thus they are *cut off from* communication with the air in the drain. *The siphon trap* should have an inspection opening

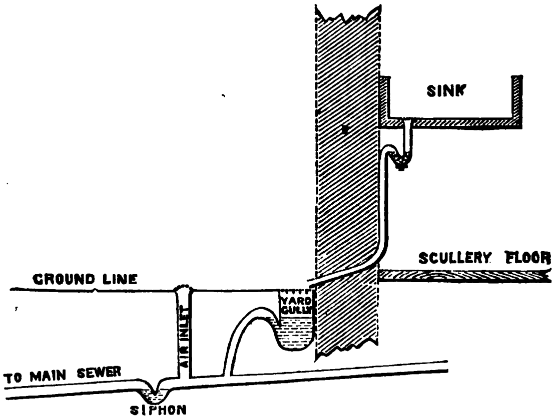
FIG. 15.



Lead Siphon (or S) Trap with Screw Cap for cleansing.

fitted with a screw cap, by means of which it can be cleansed if necessary. The D trap, often used for sinks, is a leaden box with flat sides shaped like the letter D with the round part placed

FIG. 16.



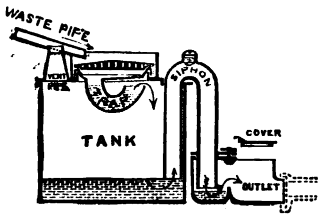
Waste Pipe of Sink, provided with S Trap and discharging over yard gully. House sewer provided with Siphon Trap and air inlet.

downwards, thus D.[1] The pipe from the sink passes through the top of it and dips into the water which it holds, and the pipe which allows the water to escape starts from the upper part of the trap. The inspection opening is placed in the side of it, while in a siphon trap the inspection opening is placed at the lowest part of the bend. The D trap is objectionable as foul matters accumulate in it. Sinks should always be placed against external walls, where it is possible,

[1] For figure of D trap see fig. 20, page 119.

as then it is much easier to carry the waste pipe outside the house. For scullery sinks a self-acting flush-tank (Fig. 17) is sometimes very useful; it consists of a tank with a trapped grating at the top of it, over which the waste pipe of the sink discharges. None of the waste water escapes from the tank until it is quite full, when the tank is nearly emptied by means of a siphon fixed at one side of it; thus sand, grease, &c., are collected in the tank and prevented from blocking the drains, and also the drains are flushed by the large body of water which is discharged through them when the tank empties itself. In country places such a tank may be made to discharge into the drains under the garden or under a field, and thus the waste water may be got rid of without the nuisance of a cesspool, and with the advantage that the soil is fertilised by it.

FIG. 17.



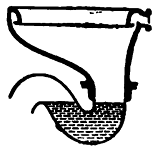
Automatic Flush-Tank.

The waste pipes of sinks and baths in the upper part of the house should be provided with siphon traps immediately below the sinks or baths, and should then be carried down and made to end over gullies in the yard: they should never be connected with the drain or with the water-closet apparatus, as is generally the case; or, still better, they should be carried straight through the wall of the house and made to end in pipes with open heads like rain-water pipes,

which themselves end over yard gullies and are not connected with the drain. The overflow pipes of cisterns should always be made to end directly in the open air, on the leads, or over the yard.

§ 52. **Water-closets.**—The simplest form of water-closet and the one best suited for careless people consists of a basin called a short-hopper with an earthenware siphon at the bottom of it. It is readily cleansed, and things which may have been accidentally or wilfully put into it are easily removed. The back of the hopper is nearly vertical, while the front slopes gradually, and it is provided with a flushing rim. This short-hopper is far better than the old conical long-hopper with the water supplied to it through a hole in the side of the basin, as the latter form is much more liable to become foul. It is very important that the hoppers should be plentifully supplied with water. Very convenient forms of closet for use in manufactories or where there are large collections of people are what are called the '*Trough*' and '*Tumbler*' water-closets. In each of these there is a watertight trough placed under a row of seats and sloping towards a pipe which is connected with the sewer. In the 'trough' closet the mouth of this pipe is closed by a plug, which is removed by an attendant once or twice in the twenty-four hours, so that the contents of the trough are allowed to run away into the sewer; the plug being then replaced and the trough charged with a little water from a tap at the

FIG. 18.

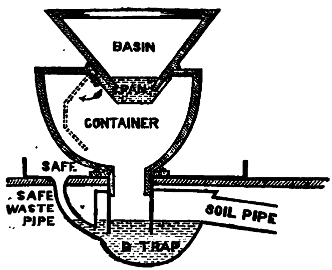


'Short-Hopper' Water-closet.

upper end the closets are again ready for use. In the 'tumbler' closet there is no plug at the mouth of the pipe at the lower end of the trough, but at the upper end is placed a bucket hanging under a tap from which water is allowed to drip. As soon as the bucket is filled up to a certain height it tips over into the trough and washes away its contents down the discharge pipe into the sewer. Self-acting flush-tanks, which can be made to discharge at required intervals, are now used for the supply of these closets.

A more complicated form of closet, and the one commonly used in houses, is the *pan* closet, in which below the conical basin there is a metal pan, capable of holding a certain quantity of water, into which the lower edge of the basin dips. This pan can be moved (by means of a 'pull-up' apparatus) inside a large iron box or *container*, placed below, so that the contents of the pan are discharged into it. From the bottom of this container passes a short pipe into a leaden D trap, usually placed below the floor, and from this D trap a four-inch leaden pipe passes into a pipe connected with the sewer, called the soil pipe of the house. The disadvantages of this form of closet are, that there is always a collection of foul water in the D trap; foul air collects

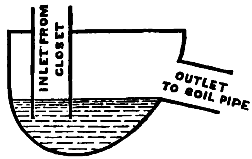
FIG. 19.



Pan Water-closet.

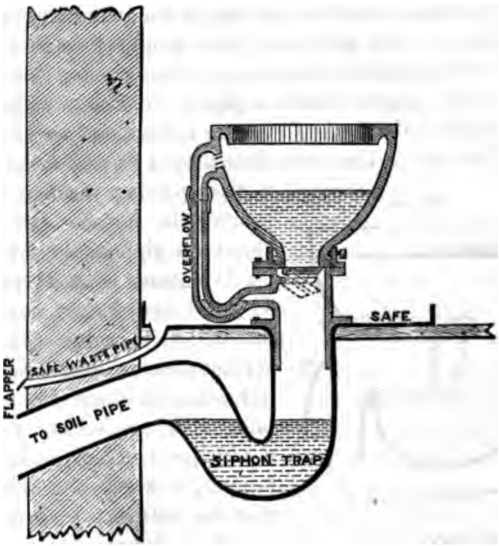
in the iron box or container and escapes into the house when the handle is pulled and the contents of the pan discharged, and this is only partly obviated by ventilating the container by a special pipe directly into the outer air; the interior of the container, too, gets very foul from the splashings on the sides; and such closets require to be frequently taken down and thoroughly cleansed. The VALVE Closet, in which there is no

FIG. 20.



D Trap.

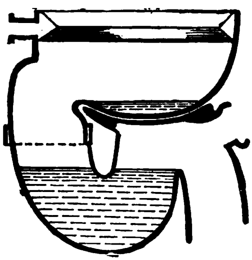
FIG. 21.



Valve Water-closet.

container under the basin, but only a small box, in which a watertight valve, which exactly fits the outlet of the basin, can be moved, is a great improvement upon the pan closet; the basin is generally provided with an overflow pipe to allow the escape of water which may run into it through a leaky supply-valve. The overflow pipe has a small siphon bend on it, and is made to end in the valve box, and the water is directed by a plate called a 'spreader,' or by the 'flushing rim' of the basin, so that it flows across the opening into the waste pipe, and charges the siphon bend, or is supposed to do so, each time that the closet is used; when this is not the case, connection is established between the air in the valve box and the house: the overflow pipe should therefore be separately supplied with water. Some valve closets are made without overflow pipes, in which case, if the supply-valve leaks the basin is filled and overflows into the safe. The valve box should be ventilated by a pipe passing through the wall of the house. In all closets a siphon should be used instead of a D trap, as solid matters do not so readily lodge in it. There are also various forms of wash-out closet, in which the basin holds a little water but does not keep as clean as the short-hopper, in which the outlet is at the bottom. Jennings's

FIG. 22.



'*Wash-out*' Closet.

'Plug' Closet consists of a pan and siphon of earthen-

ware all in one piece, the upper end of the siphon where it joins the basin being closed by a plug which can be lifted vertically by a handle in the ordinary way. By means of this plug a certain quantity of water is kept in the basin, and when the plug is raised the contents of the basin are allowed to fall into the siphon, while at the same time the valve on the service pipe is opened and fresh water is discharged from the cistern into the basin. But it is necessary to have an overflow pipe for the basin, and this is provided by a tube passing through the plug and the rod connecting it with the handle, and opening out just above the level of the water in the basin, the opening being covered with a light ball trap as an additional protection; or the plug is solid, and the overflow trapped in some way. One form of this closet is trapless, the result of which is that air from the soil-pipe and drain can enter the house when the handle is pulled up, or when the plug is prevented from closing tightly by a piece of paper getting jammed below it.

Water-closets should never be supplied directly from the main water pipe nor from the drinking-water cistern, but by means of separate cisterns or service boxes; and it is a good plan to have water-waste preventers, by means of which three gallons of water and no more are discharged each time the handle is pulled up; for mischievous persons cannot then waste the water by fastening up the handle of the closet. The soil pipe into which the closets discharge should be a four-inch drawn lead pipe, and not a seamed pipe, and should be, if possible, carried down outside *the house.* It should, in all cases, be carried up

above the roof and allowed to end wide open, so that any foul air in it is able to escape. When this is not the case, the water discharged out of one closet frequently draws some of the water out of the trap of another, and so allows the foul air which has been accumulating in the upper part of the unventilated soil pipe to get into the house. As a further precaution an air-pipe should be attached just beyond the outlet of each trap and connected with the ventilator of the soil pipe. The soil pipe may be connected by a bend with the house-drain, and so made to act as its ventilating pipe, due provision being made for an air inlet as described already. (See p. 110.)

Under water-closets and baths it is usual to place a lead tray called a *safe*, to prevent any overflow from soaking through the floor into the ceiling of the room below. With baths the safe is wanted to catch splashings over the side, accidental leakage, or overflow, in case the waste pipe gets stopped up. These safes have to be provided with a discharge pipe, which pipe is almost invariably in the case of water-closets, and frequently in the case of baths, connected with the soil pipe or with the D trap of a water-closet (as in the diagram of a pan closet, Fig. 19), having sometimes a siphon bend upon it and a contrivance called a 'Weeping Pipe,' which supplies the siphon with a little water each time that the closet handle is pulled up. Discharge pipes from safes should always end, like waste pipes of cisterns and sinks, in the outer air. They may be carried straight through the wall of the house, and ended just outside with a little swinging flap to prevent wind blowing through them, as in the

diagram of a valve closet, Fig. 21. In the case of a bath the overflow pipe from the bath may end in the waste pipe, provided this discharges, as it always should, into the open air; but the discharge pipe from the safe should end separately. Sometimes the action of the closet apparatus is made automatic, when it has to be used by careless persons. This is done by connecting it with the door, or with the seat, so that the movement of the door, or the weight of the person, causes water to flow into the basin. These arrangements are, however, liable to get out of order.

CHAPTER IX.

COMMUNICABLE DISEASES.

§ 53. **Epidemic Diseases.**—There are several classes of diseases which can be communicated from one person to another, but we shall consider here only those which are liable to become epidemic from time to time; that is to say, to spread about with great rapidity from person to person, and from one place to another. They are called *epidemic* (upon the people) as opposed to diseases such as rheumatism, ague and the like, which do not spread from place to place or from person to person and are called *endemic* (among the people). Some of these diseases are, as it were, exotic, having their home in eastern countries from which they now and then set out and travel over a large part of the world. Such are Oriental plague and cholera. The others, which are always among us, and from time

to time assume an epidemic form, are the specific fevers—a class of diseases possessing well-defined characteristics. The more important of these diseases are small-pox, scarlet fever (or scarlatina), measles, whooping cough, diphtheria, chicken-pox, typhus fever, and enteric or typhoid fever. These diseases are all communicable from one person to another. They are diseases of definite duration, and the duration of each is divided into distinct periods, the most characteristic and instructive of which is the period of incubation; that is to say, the period which elapses between the time of taking the disease and the time at which it shows itself. What is still more remarkable is that an attack of one of these diseases confers a more or less complete immunity from that disease for the rest of life. As these diseases are communicable from one person to another, we conclude that there is something in the diseased person which is or may be communicated to persons around him, and this something we call the 'poison' of the disease. We also find that in many of these diseases, as in small-pox, for example, we can take something from the body of the person suffering from the disease, and give the disease with this to persons at a distance. We find also that articles of clothing, &c., which have been in contact with the person suffering from one of these diseases frequently communicate the disease to other persons. Experiments have shown that, in several instances at any rate, these poisons consist of solid particles which will subside in liquids in which they are suspended, or may be filtered off from them, and that they are not gases or volatile liquids, as they cannot be driven

off by the evaporation of the liquids containing them, nor are they dissolved in those liquids. It has long been believed that the poisons of these diseases are living things of the nature of germs or seeds, which find the conditions suitable for their development and multiplication in the human body. This idea no doubt originated in the strong resemblance which the phenomena of these diseases bear to those of putrefaction, in the production of which we know that low forms of life are invariably concerned. The existence of the period of incubation also lends a strong support to this view, as there is no such period in cases of poisoning by means of any unorganised substances, and there is invariably such a period among the phenomena with which living things are concerned. These poisons too, like low forms of life, multiply indefinitely in suitable media. They are destroyed by the same agents—as, for example, by heat—and they agree with those low forms of life which accompany putrefaction in resisting the application of the most intense cold. In the case of several of these diseases it has now been shown that their poisons are either living organisms known as bacilli, or are chemical substances produced by these organisms, the organisms not only having been separated and identified, but having been cultivated in suitable media outside the body. So far as we know at present it appears that, wherever a case of one of these diseases is found, the poison by which it was produced was derived from a previous case. This is admitted universally with regard to most of these diseases, but by some denied with regard to a few of them, especially typhus fever, and enteric or

typhoid fever; but the evidence brought forward to show that the poisons of these diseases arise *de novo* under favourable circumstances is totally insufficient for the purpose, and only serves to show how difficult, and in many cases how impossible, it is to investigate all the ways in which these poisons may be carried about. Among the more important media which are recognised as vehicles by which these poisons are distributed are the air, in which they may be suspended and blown about, subsiding in the dust when the air is still, a notable example of this being afforded by the conveyance of the poison of enteric fever by means of air in sewers; drinking-water, which may contain suspended in it the poison of almost any of these diseases, but which is especially associated with the spread of enteric fever (and also of cholera); various articles of food, and notably milk that has been mixed with poisoned water; clothes, &c., as has already been mentioned. Passages are made by rats from one house to another, and from the drains into the basements of houses, and foul air containing the poison of one of these diseases suspended in it may, and frequently does, find its way along these into the house or from one house to another; moreover, the rats coming from the sewers may have the poisons of these diseases about them, and so may convey them to drinking-water, milk, or other articles of food. Flies, too, have been almost entirely overlooked as agents in the spread of these diseases. It may be considered as certain that they spread erysipelas, *pyæmia*, and similar diseases in hospitals. It has been established conclusively that it is by means of

flies of the same kind as the common house fly, and not by means of biting or stinging insects, that malignant pustule is spread in cattle; and there is no reason whatever why the poison of one of these diseases, as of small-pox, or of typhoid fever, may not be conveyed by flies to considerable distances. It is not at all impossible too that by means of birds, and by the feet of domestic animals, the poison at any rate of typhoid fever may be carried from midden heaps, foul ditches, &c., to distant places.

The communication of these diseases by means of articles of food that are sent from place to place is a matter difficult of investigation, and about which little or nothing is known, while the fact that their poisons may be sent about in wearing apparel, carpets, drapery, bed furniture, and may be received with a new coat, a new bonnet, or a clean pair of sheets, may well make us hesitate before we claim in any case to have investigated all the circumstances of the introduction of the poison.

§ 54. **Precautions to prevent spread of Epidemic Diseases.**—In the prevention of the spread of these diseases isolation of the person suffering—that is, his separation from healthy persons—is of the first importance, and the destruction of the poison as it leaves his body comes next. In only one of these diseases (small-pox) are we possessed of any means of preventing an attack of the disease if we are exposed to the poison of it. When a person is attacked with one of these diseases he should therefore either be sent away to a hospital in which such diseases are treated, or he *should* be placed in a room by himself (at the top of

the house if possible) from which carpets, curtains, and all unnecessary articles of furniture have been previously removed. The room should be freely ventilated by having a small fire in the grate and by opening as many windows in the staircase and in the rest of the house as the condition of the atmosphere will allow, so that fresh air may pass from the house into the sick room. The more air can be got to pass through the house, the less likely is the disease to spread. It is of course necessary that susceptible persons—that is to say, those who have not already had the disease—should be kept away from the person suffering; and although it is frequently advised to allow children to take measles in order that they may not have this disease later in life, it proves indirectly fatal to so many children and mischievous to so many others that the plan seems scarcely defensible. In most of these diseases—cholera and enteric fever being the exceptions—the poison is given out from the skin, throat, or lungs, into the air around, and so the nearer people are together and the more they are crowded the more likely are these diseases to spread; but this is especially true of typhus fever, which indeed only spreads in crowded places; and when imported accidentally into less crowded districts, seldom spreads beyond the house to which it is taken, and often does not spread beyond the patient first attacked.

After isolation, the next object to be aimed at is the destruction of the disease poison, which is given off in one or more ways from the body of the patient during the greater part of the illness. It is possible

that all the excretions contain the poison in every one of these diseases; but in each of them it appears ~~to be got rid of~~ more through one channel than through the others. Thus in small-pox, scarlet fever, and measles it is especially got rid of from the skin, being contained in the crusts of small-pox, and in the scales which fall off during the progress of the other two diseases. In diphtheria and also in scarlet fever the poison is chiefly separated from the mucous membrane of the pharynx; in typhus fever especially from the lungs, and in whooping-cough by the same channel; so that in all these diseases the poison gets into the air around, and it is dangerous for any one who has not had the disease to come near persons suffering from it. In enteric or typhoid fever (just as in cholera), on the other hand, the poison is especially got rid of through the intestinal canal, and is swamped in a mass of liquid, so that it does not readily get into the air around, and this is why attendants do not often take the disease in these cases. The contagiousness or communicability of these two diseases has from this fact even been denied, and it has been stated that there is plenty of evidence to show that the fresh excretions do not contain the poison of the disease—at any rate in the case of enteric fever—but that it is formed only during decomposition and even that it may thus originate in intestinal excretions, whether those of an enteric fever patient or not. The evidence upon which these statements rest is insufficient. We can no more tell that the fresh excreta of an enteric fever patient do not contain the poison of the disease by looking at them, than we could tell that a

glass of beer does not contain strychnine by looking at it; and the fact that such decomposing excreta are poisonous, and are admitted to be capable of communicating disease when water polluted by them is drunk, and that they may moreover contaminate the air around, would rather lead us to the conclusion that the poison is contained in the fresh discharges, and that it is not produced during their decomposition, but merely carried up into the air around by the bubbles of gas which escape. This is a very important matter, as, if these discharges do contain the poison of the disease, it is our duty to try to destroy it as fast as it leaves the body. If they do not, such a precaution would be obviously superfluous; and so if erroneous views on this subject are promulgated, incalculable mischief may be done.

§ 55. **Disinfectants.**—The agents by which the poisons of these diseases may be destroyed are termed disinfectants; and it is important that they should neither be confused with antiseptics (such as common salt) which prevent putrefaction, nor with deodorants (such as charcoal) which remove foul smells. Destruction by fire of all the infected articles is the surest way to prevent the spread of these diseases; and although this plan can only be occasionally resorted to, it is well in all cases to burn everything that can be spared. Next to this, exposure to superheated steam at a temperature of from 250° F. to 300° F., in a suitable chamber, is found to be sufficient thoroughly to disinfect articles of clothing, so that they can be, *and are frequently*, used again immediately by other *persons without* conveying the disease. Disinfection

by means of hot air is not so efficacious. By prolonged boiling in water, especially if one of the disinfectants mentioned below be added, clothes may also be disinfected. Among gaseous disinfectants the most important and effective are sulphurous acid, produced by burning sulphur or bisulphide of carbon in the air; peroxide of nitrogen, formed by dissolving copper turnings in nitric acid, when a gas is given off which forms brownish-red fumes of peroxide of nitrogen by combining with oxygen in the air; chlorine, produced by moistening chloride of lime with water, or with a dilute acid or by

ERRATUM

Page 131, line 8 from bottom, *for* Condy's Fluid (solution of potassium permanganate), *read* A strong solution of potassium permanganate, which is

Condy's Fluid (solution of potassium permanganate), a powerful antiseptic and deodoriser, has also under certain conditions disinfecting properties; and the solutions of many mineral salts, notably those of copper, lead, zinc, aluminium, and iron, are believed to be capable of destroying the poisons of diseases when mixed in sufficient quantity with fluids containing them, though the evidence with regard to the dis-

infecting properties of these substances is much less complete than it is in the case of those before mentioned.

§ 56. **Disinfection.**—In all cases, but especially in those of enteric fever or cholera, the discharges of the intestinal canal and kidneys should be received into vessels containing a disinfectant. For this purpose a solution of green copperas (iron proto-sulphate) containing a pound in a gallon of water has been recommended by Pettenkofer; of this solution half a pint should be used each time. A dessert spoonful of strong carbolic acid mixed with a little water is sometimes substituted for the iron solution, or used with it; but as a great many persons have been poisoned by accidentally taking carbolic acid, it is not advisable that this disinfectant should be placed in the hands or within the reach of careless persons. Some more disinfectant should also be added to the discharges before they are thrown away, and the closets, sinks, &c., should be well flushed with the same solution once or twice daily. In country places it is well to bury the infected discharges in the ground at a distance from houses and especially far removed from any source of drinking-water. The spittoon with which the patient should be provided should also have a small quantity of a disinfectant solution in it. The patient should not use pocket-handkerchiefs, but small pieces of rag, which should be immediately burned after being used. In small-pox, scarlet fever, and measles the skin should be rubbed *every day with* camphorated oil. This is agreeable to *the patient, and* prevents infected particles from the

skin from being distributed in the air of the apartment. A solution of carbolic acid in glycerine has been also found advantageous as an application to the eruption of small-pox in its early stage. In diphtheria and scarlet fever, the throat should be washed with a gargle containing Condy's Fluid, or with a weak solution of sulphurous acid. Typhus fever is the only one of these diseases in which we have evidence that a very marked advantage is gained from the use of aerial disinfection in the sick room. Dr. Parkes has suggested that this may be due to the fact that the poison in this disease is continually given off into the air in large quantities from the skin in what may be called a free state. As he says:—'The agent is not enclosed in quantities of dried discharges and epidermis, as in the exanthemata, and is therefore less persistent and more easily destroyed than in those cases.' The disinfectant which has been most efficacious in cases of typhus fever is peroxide of nitrogen. It is quite possible that aerial disinfection may be useful in all these diseases when it is not pushed to the extent of causing the atmosphere to be irritating to the patient. The conclusion that has been drawn—that because large percentages of disinfectants are required to destroy the infective properties of liquids containing the poisons of such diseases, it follows that when suspended in the air they are not attacked and destroyed by much smaller percentages of the same disinfectants —is entirely unwarranted and will probably turn out to be erroneous. The cups, glasses, spoons, &c., used by the patient should be reserved exclusively for his use, *and before* being used by any one else should be

washed first in water containing Condy's Fluid and then in hot water. No food should be kept in the sick room, and no article of food that has been taken into it should be eaten by anybody except the patient. The attendant should not wear woollen clothes, as infectious poisons are liable to hang about them. Glazed cotton is the best material for the dresses of nurses. Visitors should not be allowed to go into the room even if they have had the disease themselves previously, as they may carry the poison away in their clothes; and children from a house where there is one of these infectious diseases should not be sent to school, as they may carry the poison with them in their clothes, although not suffering from the disease themselves. All bed and body linen, as soon as it is removed from the patient, and before it is taken from the sick room, should be placed in a tub of water containing Condy's Fluid or carbolic acid, and should be afterwards well boiled in the house. It must not be sent to the laundry with other things, as this is one of the commonest ways in which several of these diseases spread. The dust should be collected and burnt in the room. In those diseases in which the use of camphorated oil for the skin has been recommended, the patient should, when he is well enough, be washed with warm water—carbolic acid soap being used. He must not be allowed to mix with other persons until all the skin has become perfectly smooth.

The room and all articles in it, including everything that has been worn by the patient during his illness, require to be disinfected. The bedding and clothes are best disinfected by being sent to be baked

in a hot air disinfecting chamber. Where this cannot be done they should be hung up on lines, or propped up in the room and disinfected with the other contents of the room in the following manner:—Windows and doors (all but one) should be shut and paper pasted over the crevices inside; then a bucket containing a little water should be placed on the floor, and an iron vessel, such as an old saucepan, placed either on a flowerpot turned upside down in the water, or on a pair of tongs laid across the bucket. Broken pieces of roll sulphur (from 1lb. to 1½lb. for each thousand cubic feet) should be placed in the iron vessel and lighted either by a live coal or by pouring spirits of wine on to them and setting it on fire with a match. The person who does this must then go out and close the remaining door, pasting paper over the keyhole and crevices outside, and the room must be left closed with the sulphur burning for some hours, but not all night. The doors and windows should then be opened and a current of air allowed to pass through the room. The paper should be stripped off the walls and burnt. This must be done in every case to make the disinfection complete, as disease-poisons hang about wall papers sometimes for years. The ceiling and walls are next to be lime-whited and the floor and woodwork well washed with soap and water containing chloride of lime or carbolic acid. The room should, if possible, be left unoccupied for a week or so, but although families are frequently obliged to turn into the rooms on the evening of the same day, it scarcely ever, if ever, happens that the disease again breaks out in the same place. In case

of death the body should not be removed into another room, and it is advisable to sprinkle it well with carbolic powder when in the coffin, and to bury it without any delay.

§ 57. **Illegal Acts.**—It should be borne in mind that any person who enters a public conveyance while suffering from any infectious disease (without notifying the fact to the driver), or unnecessarily exposes himself in any public place, or who allows any one in his charge to do so while thus suffering, or who exposes or parts with any infected articles which have not been properly disinfected; any driver of a public conveyance who does not immediately have it disinfected after a person suffering from such disease has (to his knowledge) been conveyed in it; and, lastly, any person who lets an infected room or house before it has been disinfected—does an illegal act, and renders himself liable to be prosecuted under the Sanitary Act, or under the Public Health Act, and fined.

CHAPTER X.

SMALL-POX AND VACCINATION.

§ 58. **Natural Small-pox.**—Small-pox requires to be considered separately; in the first place, because it is certainly the most dreadful disease that afflicts us; and in the second place, because we are happily able to prevent its attacking us. It is extremely contagious, and far more fatal than any of the other communicable fevers, sometimes killing even more than 50 per cent. of those whom it attacks in unpro-

tected communities. During the last century this disease killed on an average nearly half a million of people in Europe annually, and was severely epidemic about once in three years. In some years it caused half the deaths of children under ten years of age. It produced frightful disfigurements of the features, and caused from one-half to two-thirds of all the cases of blindness in Europe. In Iceland in the year 1797 it caused a third of all the deaths in the island. When introduced into countries where it had not yet appeared it caused frightful havoc among the inhabitants. Among the North American Indians it spread like 'a fire consuming the dry grass of the field,' and persons who were not yet attacked by it slew themselves and their families rather than face this terrible disorder. When it first visited Ceylon it carried off, according to a very moderate calculation, one-sixth of the inhabitants. This disease, although, as Dr. Guy well says, it was 'specially greedy of the blood of children,' spared no age, no rank of life, and no country, nor was it deterred by any climate. In the last century, and in the centuries before, it was just as much dreaded in the upper ranks of society as among the poor, and the disfigurement produced by it was so universal that every woman whose face was not pitted with the small-pox was regarded as a beauty. As lately as in 1772 Maitland speaks of 'the havoc made in great families not many months since by that mighty disease, which seemed then to go forth like a destroying angel subduing all before it.' That this disease is no respecter of persons or conditions of life is well shown by the fact that six

members of the family of William III. died of it, and that he himself suffered severely from it and was permanently marked by it.

During the last century there were 34 years, in each of which small-pox caused in England more than 100 out of every 1,000 deaths from all causes, or more than one-tenth of the total deaths. Of these 34 years there were five, in each of which small-pox caused more than 150 deaths out of every 1,000 from all causes, and these five years were all in the second half of the century, so that the epidemics in the second half of the last century were more severe than in the first half, and the most severe epidemic of all was in the year 1796, when small-pox caused no less than 184 deaths out of every 1,000 deaths from all causes. Dr. Guy points out that 'in the last ten years of the century it was more than one hundred times as fatal as diarrhœa and its allied diseases; six times as fatal as apoplexy, palsy, and sudden death taken together, and seven times as fatal as the measles.' During the last century, in fact, it caused in England one death in every twelve from all causes, and in France one in every ten.

§ 59. **Inoculation.**—Small-pox is one of those diseases which a person rarely has twice. One attack of the disease in the majority of instances confers an immunity for the rest of life. Still it is important to remember, as mentioned in the previous chapter, that persons may have the disease twice, three times, or even oftener. The fact that only a small number of persons caught the disease a second time if they survived the first attack was supplemented by the dis-

covery, which appears to have been made in various parts of the world and even among savage tribes, that when some of the poison was taken from a pustule of a person suffering from small-pox and inoculated into the skin of a healthy person the disease so contracted was very much less fatal than when it was caught in the ordinary way. This practice of *inoculation* was introduced into England from Constantinople by Lady Mary Wortley Montagu early in the last century, and it soon became general. It was tried first on some condemned criminals, who were thus made useful to mankind; next on some pauper children; and the experiments proving successful, the members of the Royal Family were actually inoculated with small-pox poison, and the practice soon became general, not only in England but in other countries of Europe. This is a most astonishing fact, and shows us at once, in the most striking manner, the fearful nature of the disease. Here was one of the most loathsome diseases, the most fatal disorder to which mankind has ever yet been subject, and yet people deliberately took the poison of this fearful disease and inoculated their children and themselves with it. Why was this? There is only one explanation of the fact. The disease was so universal that every one considered himself certain of taking it, and as it was less fatal when deliberately inoculated than when caught in the ordinary manner, it was far better to be inoculated with the poison, to take the disease in its milder form, and have done with it, than to catch it in the ordinary way and run a much greater risk of being killed by it. The chance of not taking it at all was so small that it was

not worth considering. By the practice of inoculation the fatality of the disease was reduced from one death in five of those attacked, which we may take as the average of the natural small-pox, to one death in fifty of those attacked; but, as every inoculated person became a fresh centre from which the disease could spread, epidemics were increased in frequency, so that in the 63 years during which inoculation was practised there were no fewer than 50 epidemics, which is equivalent to 84 in a century, whereas previously there had been 71 or 72 epidemics in each century.

§ 60. **Vaccination.**—It was frequently noticed that during epidemics of small-pox somewhat similar diseases were prevalent among cattle—diseases known as cow-pox, sheep-pox, and horse-pox—and it was well known among the persons connected with dairies that those who had contracted cow-pox while milking animals suffering from that disease were not susceptible to small-pox.

Cow-pox appeared in some Gloucestershire dairies near the end of the last century in a very severe form, and Dr. Jenner observing the fact that the persons engaged in milking were not subject to small-pox and were not afraid of it, determined to try whether a person who had been given cow-pox by inoculation was afterwards capable of contracting small-pox in the same manner, and he proved experimentally that persons who had either taken cow-pox by contagion from the cow, or to whom it had been given by the operation known as 'vaccination'—that is, by inoculation of the cow-pox matter, or by inoculation of the same matter taken from a human being suffering from

the cow-pox—were equally insusceptible to the action of the small-pox poison even when they were directly inoculated with it.

The first case upon which Dr. Jenner tried the experiment was that of a lad upen whom he inoculated the virus taken from the hand of a woman who had been accidentally infected with cow-pox, or vaccinia, from the cow. Some months afterwards he inoculated the same lad with small-pox matter, and a second time five years afterwards, without the production of small-pox in the lad on either occasion. Dr. Jenner began to experiment in 1795, and he published his results in a pamphlet in 1798, giving a record of many unsuccessful attempts to inoculate small-pox upon persons who had contracted vaccinia either accidentally or by vaccination. These experiments were confirmed by Dr. Woodville, who was physician to the Small-pox and Inoculation Hospital in London, and who, within two years, vaccinated not less than 7,500 persons, about half of whom he subsequently inoculated with small-pox, and many of whom he also exposed freely to the operation of small-pox contagion without any of them contracting the disease.

Many instances are on record of vaccinated infants not contracting small-pox although their mothers suffered severely from the disease while nursing them, and in France 'not only was tentative inoculation with small-pox virus practised, but (vaccinated) infants who had been thus unsuccessfully inoculated were designedly brought into close relationship with other children suffering from small-pox; shut up with them in the same room, put into the same bed, covered with their clothes,

made to eat out of the same plate and drink out of the same glass, and all without in any instance imparting to them small-pox.'—(*Ballard.*)

§ 61. **Vaccination Statistics.**—Thus was Dr. Jenner's statement that the cow-pox protects the human system from the infection of small-pox completely proved by crucial experiments, not only by himself but by his own contemporaries. Even in his own lifetime Jenner was able to adduce evidence on a considerable scale of the power of vaccination to prevent the small-pox. He writes:—'From the year 1762 to the year 1792 the number that died of small-pox in the Danish dominions amounted to 9,728. About the year 1802 vaccination was first introduced and the practice became general but not universal; however, 58 persons only died of small-pox to the year 1810. Vaccination by command of the king was now universally adopted and small-pox inoculation prohibited, and from the year 1810 to 1819 not a single case of small-pox has occurred.' And again he says:—'From Bombay I learn that small-pox there is completely subdued, not a single case having occurred for the last two years.' In England the practice of vaccination was gradually adopted with the result of a progressive lowering of the number of deaths from small-pox, as was shown by a report prepared by the Small-pox and Vaccination Committee of the Epidemiological Society of London. From this report we find that in the three *years* immediately preceding the provision of gratui*tous vaccination in* 1840 the average annual number *of deaths from small-pox* in England was very nearly

12,000; that during the period from 1841 to 1853, when vaccination was gratuitous but not compulsory, it was under 5,250; while during the period from 1854 to 1863, after the passing of the Compulsory Vaccination Act in 1853, the average annual number of deaths from small-pox was only 3,351. Or if we take longer periods of years, it was shown that in the last half of the last century, from 1750 to 1800, the number of deaths from small-pox was actually 96 out of every 1,000 deaths from all causes; and in one year, as already stated (1796), no less than 184 out of every 1,000 deaths were from small-pox; during the first half of the present century, from 1800 to 1850, when vaccination had been partially introduced, instead of 96 there were only 35 deaths from small-pox out of every 1,000 deaths, while from 1850 to 1860 (vaccination having been made compulsory in 1853) only 11 deaths out of every 1,000 were from small-pox. It was shown in a Parliamentary return in 1853 that whereas in places in the United Kingdom where there was then no law compelling vaccination the number of deaths from small-pox in 1,000 deaths from all causes varied from 16 in London to 60 in Connaught, and was almost exactly 22 in England and Wales and 49 in Ireland, it varied in countries where vaccination was directly or indirectly compulsory, from *two* in Bohemia and Lombardy to a little over *eight* in Saxony. Since 1837 the registration of deaths in England and Wales has been very satisfactorily carried out, and we find that during the 16 years from 1838 to 1853, while vaccination was gratuitous but not compulsory, the annual number of

deaths from small-pox in England and Wales averaged 420 per million persons living, while in the 26 years from 1854 to 1879 it averaged scarcely 209—in other words, the death-rate from small-pox during the period of compulsory vaccination has been just under half of what it was even during the period when vaccination was gratuitous but not compulsory. In the last century the annual deaths from small-pox were between 2,000 and 3,000 per million persons living.

From a table prepared by Mr. Simon it appears that while the death-rate amongst unvaccinated persons in the different countries of Europe varied from 14½ to nearly 54 per cent., that among the vaccinated persons varied from ½ to 12½ per cent. of the total cases; and whereas the average death-rate of the unvaccinated is at least 20 per cent., that of the vaccinated is only 5¼ per cent. of the total cases.

The statistics of Sweden show the results of the introduction of vaccination in a very remarkable manner. In the 61 years from 1749 to 1809 inclusive there was only *one* year in which the deaths from small-pox in that country were under 1,000, and there were *nine* years in which they were over 10,000, whereas in the 63 years from 1810 to 1872 inclusive, while vaccination was practised, there were no less than 48 years in which the number of deaths from small-pox was under 1,000, and in no year did the deaths reach 10,000 or even 3,000. The greatest number of deaths in any year in the period before vaccination was 16,607 and the least number 671, while the greatest number of deaths in any year

during the vaccination period was 2,488 and the least number *two.*

§ 62. **Degree of Protection.**—There are degrees, however, in the protection afforded by vaccination according to the way in which the operation has been performed. Mr. Marson, who was resident surgeon at the London Small-pox Hospital for many years, constructed a table which showed the relative protection afforded by good and by inferior vaccination as evidenced by the number and character of the scars produced. This table shows that among persons who were said to have been vaccinated but had no scar the death-rate was nearly 22 per cent.; among those having one scar it was $7\frac{1}{2}$ per cent.; among those having two, a little over 4 per cent.; among those having three, less than 2 per cent., and among those having four or more scars about $\frac{3}{4}$ per cent.; while subsequent information has enabled Mr. Simon to show that the fatality of small-pox in persons having four or more cicatrices is rather less than $\frac{1}{2}$ per cent. These results have been confirmed in every subsequent epidemic of small-pox, and it has even been shown that the death-rate among persons who have good vaccination marks is less than among those who have imperfect marks. Thus Dr. Gayton in an analysis of 6,553 cases of all ages admitted into the Homerton Small-pox Hospital from February 1, 1871, to December 1, 1878, shows that while the mortality among the unvaccinated was $45\frac{3}{4}$ per cent., and that among those stated to have been vaccinated but having no scars $27\frac{1}{4}$ per cent., that among the *vaccinated* with imperfect marks was only just over

11, and that among the vaccinated with good marks just under $3\frac{1}{3}$ per cent. These facts show that even where vaccination has not prevented persons from contracting the small-pox it has modified that disease in such a manner as to render it much milder and much less fatal. This is also well shown by the fact noted by Dr. T. C. Fox, the medical superintendent of the Fulham Hospital, in his report on the cases of small-pox admitted into that institution during the year 1877, that whereas the average duration of stay in the hospital of patients who recovered, varied among the vaccinated from $32\frac{1}{4}$ days among those who were only indifferently marked to $22\frac{1}{2}$ among those who had five or more marks, the stay of the unvaccinated who recovered averaged no less than $46\frac{1}{4}$ days. From the enormous number of cases that Mr. Marson saw during upwards of thirty years' residence at the London Small-pox Hospital he was able to deduce the precise effect of vaccination in modifying already contracted small-pox, and he came to the following conclusions :—That if an unvaccinated person caught small-pox, say on Monday, and was vaccinated on or before Wednesday, he contracted vaccinia and not small-pox. If the vaccination was postponed till Thursday he took both diseases, the small-pox being modified ; but if he were not vaccinated until Friday, he would contract unmodified small-pox.

That successful vaccination in infancy is an efficient protection against small-pox up to about fifteen years of age is shown by the following facts, taken from the Report of the Managers of the Metropolitan Asylum District for 1870–2 :—Of 3,085 consecutive

cases, 926 were under fifteen years of age. Of these 402 were unvaccinated and gave a mortality of 41 per cent.; 104 had bad or indifferent vaccination marks and gave a mortality of 12 per cent. The 143 cases with one good mark gave a mortality under 1½ per cent.; while there were 277 cases, with two or more good marks; and not one of them died. It is, therefore, important to insist on the production of good vaccination marks, and as the mortality at all ages has been before shown to decrease as the number of marks increases, and to be under one-half per cent. with four or more good marks, the production of four good marks should be considered as the test of efficient vaccination.

Vaccination is much more successful when practised from one child to another or 'from arm to arm,' as it is called, than when lymph preserved in tubes or upon points is used, and the former practice should be adopted as much as possible.

§ 63. **Re-vaccination.**—Vaccination in infancy is not a complete protective against small-pox for the whole of life. During Jenner's lifetime there were no cases of vaccinated persons who contracted the small-pox for about fifteen years after vaccination was introduced, but then such cases began to appear. Now this, as well as the fact that the deaths from small-pox are fewest from ten to twenty years of age, and increase in number afterwards, shows very clearly that it is necessary that persons should be vaccinated again between those ages. This practice is called re-vaccination, and where it is thoroughly carried out small-pox is practically exterminated. In the army re-vaccination is compulsory,

and the following are some instances of the results attained by it, as shown by Dr. Balfour from the records of the Army and Navy Medical Department :— In the twenty years from 1817 to 1836 in Dragoon regiments and Guards, with an aggregate strength of 44,611 men, of 627 deaths only *three* were from small-pox. Among the troops at Gibraltar with the same strength, of 1,291 deaths only *one* was from small-pox. In the West Indies, in spite of several epidemics of small-pox, 'there were *no deaths* either among the British or white troops, of whom the aggregate strength was 86,661 and with a total mortality of 6,803. Among the black troops on the same station, with an aggregate strength of 40,934 and a mortality of 1645, there was *not one case* of small-pox.' In Malta during twenty years, in spite of the fact that small-pox raged all over the island twice, in 1830 and 1838, destroying 1,169 persons, there were only *two* deaths among the British troops, the aggregate strength of which was 40,826.—(*Aitken.*)

We have also the very striking evidence among the residents and nurses in small-pox hospitals who are exposed continuously to the poison of the disease. Mr. Marson tells us that during thirty-eight years while he was resident at the London Small-pox Hospital not a single nurse took the disease, the rule being that every nurse is vaccinated within three days after she enters the hospital. In the report of the managers of the Homerton Small-pox Hospital on the epidemic of 1870 to 1872 it is stated that 'all the nurses and servants, to the number at one time of upwards of 300, who are hourly brought into the most

intimate contact with the disease, who constantly breathe its atmosphere and than whom none can be more exposed to its contagion, have, with but few exceptions, enjoyed complete immunity from its attacks. The exceptions were cases of nurses or servants whose re-vaccination in the pressure of the epidemic was overlooked and who speedily took the disease.' As Dr. Gayton says :—'That the operation repeated after a certain age does confer an almost absolute protection against the disease, we, who spend the whole of our lives in this hospital are examples.' Re-vaccination is in fact a much more certain preventive of small-pox than a previous attack of small-pox is; for whereas there are in every epidemic numerous instances of persons having the small-pox for the second time and not unfrequently having it severely and even dying of it, during the epidemic just mentioned out of nearly 15,000 cases treated in the London hospitals there were only four who presented signs of re-vaccination, and these four were mild cases; so that it may be truly said that a person who has been vaccinated as an infant and successfully re-vaccinated at from twelve to fifteen years of age is almost absolutely certain that he will never contract the small-pox and is far more protected than he would be if he had already had it—unless, indeed, he happens to be one of those rare instances of an individual who has a personal susceptibility to this disease.

The evidence in favour of re-vaccination is so overwhelming that in one country in Europe a law has been recently passed making re-vaccination compulsory. *In* Prussia, although vaccination was compul-

sory in the army and navy, among candidates for appointments in the Government schools, &c., it was never made compulsory even for infants among the civil population. The epidemics in the country became so frequent and so fatal, while in other German States, in which vaccination had been compulsory for some years, the death-rate from small-pox was very slight, that the German Government, after carefully investigating the matter, passed a law in March 1874, making the vaccination of infants, and the re-vaccination of children of riper years, compulsory throughout the whole of the German Empire. (See section 67).

§ 64. **Other Diseases.**—It has been suggested that other diseases are sometimes communicated by vaccination. This never happens when vaccination is properly conducted, and very rarely indeed when it is not. It has been demonstrated that the lymph of the vaccine vesicle is capable of giving vaccinia only whatever may be the disease of the child from whom it is taken at the same time. Mr. Marson, who had vaccinated more than 50,000 times, stated that he never knew of the communication of any other disease than vaccinia by vaccination; and Dr. West, of the Children's Hospital, London, with his enormous experience, gave similar evidence. When cases of disease stated to have been caused by vaccination are investigated, it is found in almost every instance that they had nothing to do with the vaccination, either following it accidentally or being cases of inherited disease. In consequence of the objections of some to the practice of vaccination from human beings, it has been pro-

posed to vaccinate children directly from calves suffering from the cow-pox—a practice which has been very successful in Belgium and in the United States—and there is no reason why both methods of vaccination should not be practised.

§ 65. **General Death-rate.**—As a matter of fact the death-rate in every country in Europe has decreased since the introduction of vaccination; and although we cannot attribute the whole of such decrease to the diminution of the mortality from small-pox by means of vaccination, nor even to the abolition of the indirect evil effects produced by small-pox, we are certainly justified in attributing part at any rate of this decrease to the prevention of small-pox and its results, both direct and indirect, by means of vaccination.

§ 66. **English Law.**—By the English Vaccination Acts the parents are bound to have a child vaccinated before it is three months old, except in instances where the medical attendant gives a special certificate to the effect that the child is too ill to be vaccinated, and parents are fined or imprisoned for neglecting to have their children vaccinated. This is as it should be, for an unvaccinated person is a danger to the community at large, who cannot be said to be by any means completely protected against small-pox. Every parent who objects to have a child vaccinated should remember that more than 55 per cent. of the unvaccinated children under *five* years of age who contract the small-pox die of it; whereas, as has been already stated, there were among more than *three thousand* consecutive cases of all ages, treated

in the Metropolitan Small-pox Hospitals during the severe epidemic of 1870–72 *no deaths from small-pox of children under fifteen years of age* who had *two* or more good vaccination marks.

Vaccination, in fact, results in the substitution of a mild disease, which kills no one, and seldom causes more than a temporary indisposition, for the most dreadful and the most universal of all the infectious diseases.

§ 67. **Results of the German Law.**—In 1884 the German Government appointed a Commission, consisting partly of supporters and partly of opponents of compulsory vaccination, to investigate the results produced by the law of 1874. Their report shows that in Prussia the average death-rate from small-pox between 1847 and 1874 (excluding the great epidemic of 1871 and 1872, which caused over 250 deaths per 100,000 of the population) was 24·66 per 100,000 persons living, whereas from 1875 to 1881 it was only 2·18, while in Austria, where there is no such law in force, the annual death-rate during the first period (excluding the great epidemic of 1872-3-4, which caused over 230 deaths per 100,000 of the population) was 37·95, and during the second period no less than 44·77; that *in the Prussian army no death from small-pox has occurred since the law was passed*, while in the Austrian army the death-rate has varied from 10 to 25, and in the French army from 8 to 28, per 100,000 men annually; that in the large towns of Germany small-pox, as a fatal disease, has been almost exterminated since 1874; for instance, during the nine years from 1875 to 1883

inclusive, there were four years in which there were *no deaths* from small-pox in Hamburg, and five in which there were none in Munich, while in Berlin itself the annual death-rate from this disease averaged under 17 *per million* inhabitants; whereas in London during the same period it averaged 258, in Paris 332, in Vienna 892, and in Prague 1,436 per million inhabitants. Thus, in the large German towns small-pox has not been a serious disease since the epidemic of 1871-2, whereas in London, Paris, Vienna, and other cities not protected by a law compelling re-vaccination, the mortality from it has attained the same proportions that it had before that epidemic. These results show conclusively that by the compulsory practice of vaccination, followed by re-vaccination, this terrible disease may be almost, if not entirely, exterminated.

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